Performance and Structures of the German Science System 2012

Carolin Michels, Junying Fu, Peter Neuhäusler, Rainer Frietsch

Studien zum deutschen Innovationssystem
Nr. 6-2013

Fraunhofer Institute for Systems and Innovation Research ISI

February 2013

This study was conducted on behalf of the Expertenkommission Forschung und Innovation (EFI). The results and interpretations are the sole responsibility of the institute conducting the study. The EFI exercised no influence on the writing of this report.

Studien zum deutschen Innovationssystem

Nr. 6-2013

ISSN 1613-4338

Publisher:
Expertenkommission Forschung und Innovation (EFI)
Geschäftsstelle
c/o Stifterverband für die Deutsche Wissenschaft
Pariser Platz 6
10117 Berlin
http://www.e-fi.de/

Contact address and further information:

Rainer Frietsch
Fraunhofer Institute for Systems and Innovation Research ISI
Competence Center Policy and Regions
Breslauer Strasse 48
76139 Karlsruhe
Phone: +49-721-6809-197
Fax: +49-721-6809-176
e-mail: rainer.frietsch@isi.fraunhofer.de

Contents

Figures

Tables

0. Summary

Publications in an international comparison

In the past 10 years, Germany has showed a continuously increasing trend and always been ranked in the fourth or third place worldwide in terms of the number of publications and citations respectively. German authors contribute 7.2% of total scientific publications but receive 9.8% of total citations in 2009. Similar to other large industrialized countries, Germany's share of publications has reduced slowly but constantly during the last decade due to the dramatic growth trends in threshold countries, first of all China. However, the German share in publications has been rather stable since 2008. Germany displays an increasingly upward trend in its citation rate, which is distinctly above the world average. Germany's citation rates without non-English papers have always been beyond the Great Britain's level, and reached a similar high level like the USA in the last two years. Considering the indices Scientific Regard (SR) and International Alignment (IA), Germany's IA index has promoted up to 26, a value at a similar level as Great Britain, implying German scientists have increasingly released their achievements to the international community in journals with higher visibility; although it had always been similar to those for other leading industrialized countries like the United States in previous years, German SR value experiences a large margin decline in 2009, which is caused by both its comparative rise of expected citations and its comparative fall of observed citations. Smaller European countries like Switzerland present high SR as well as IA values. As to the disciplinary profile, Germany shows high specialization values in "nuclear technology", "medical engineering", "geo-science" and "biotechnology", displaying a portfolio that differs from those of China and Great Britain.

Concerning publication activities of BRICS, China has become the second largest paper producer, while its citation rate remains below the world average as do those of other threshold countries. Russia is an exception compared with other BRICS countries showing obviously and continually decreasing shares of publications and citations partly because of its relative independent native language scientific community. China and South Africa show very positive SR values in combination with still very negative IA values due to publications in journals with limited international visibility.

International co-publications

Germany's absolute number as well as the share of internationally co-authored publications increased in the last years. However, a similar statement also holds for most other countries. Nonetheless, the increase in collaboration is especially observable after 2008. German co-authorships with EU and BRICS countries were especially intensified in the recent period.

International collaborations most frequently happen in fields of German non-specialization, i.e. Food and Nutrition, Chemistry, Pharmacy, Computers, "Ecology and Climate", Agriculture and Forestry. One explanation could be that the number of potential collaboration partners is restricted within Germany, but high outside Germany. Vice versa, the shares of co-authored publications are lower in those scientific fields, in which Germany is specialized and which play an outstanding role in the German profile. Finding national co-authors might be easier here.

1. Introduction to this issue

The creation, diffusion and application of scientific knowledge are crucial foundations in the technological activities and are also key elements in the performance of a national innovation system. Consequently, the topic has been regularly analyzed for years in the studies of the German innovation system. Basic scientific research plays a significant role in technological development. First of all, industrial capabilities and competencies clearly rely a great deal on highly skilled personnel as part of the major source of innovation, which heavily depends on the success in training and education during the scientific research. Also, scientific achievements are definitely substantial bases of technological development and innovation. Nonetheless, the relationship between science and technology is difficult to prove directly and obviously since knowledge transfer is a comparatively complex and time consuming process which is affected by a number of factors.

However, it is still difficult to evaluate scientific performance appropriately and wholly especially since there are marked differences between the scientific disciplines. Therefore, besides qualitative assessment like e.g. peer review, experts have developed quantitative methods. These bibliometric metrics use statistics of scientific publications and their citations to measure the performance and impact of national science systems, parts of national innovation systems. The underlying assumption is that impact can be measured by citations since scientific achievements are mostly published in journals, so that other scientists can access it and consequently cite it if they deem it appropriate. This present study analyses data related to both science areas that have a close link to technology, and the natural, life, engineering and social science as a whole.

In this study, Germany's trends in publication and citation performance are analyzed in a global context during the period between 2001 and 2011. At the same time, BRICS, the five leading threshold countries, are also closely observed in terms of their scientific performance. Furthermore, increasing globalization has led to the increase of international collaboration in science and technology, which could promote the sharing of competences and the production of new scientific knowledge. Here, international co-publication analyses, i.e. descriptive analysis as well as network analysis, are conducted in order to strengthen German cooperation economically with the best candidate countries all over the world.

2. Methodological basis

The analyzed data are retrieved from the Science Citation Index Expanded (SCIE) and the Social Science Citation Index (SSCI) that are sub-products of the database Web of Science (WoS) during the period 2001-2011. The SCIE and the SSCI, which are multidisciplinary scientific databases, are considered to be a solid basis for bibliometric analysis. These databases broadly cover the natural and engineering sciences, and the medical and life sciences as well as the social sciences. Thomson Reuters, the producer of WoS, evaluates journals for coverage in terms of the journal's basic publishing standards, its editorial content, the international diversity of its authorship, and the citation data associated with it, and focuses on English language journals because English is regarded as a universal language of science. However, regional journals, targeting a local rather than an international audience and requiring less emphasis on extensive international diversity, are increasingly indexed from 2007 to 2009 (Testa 2012). In general, German scientific output as well as its ranking would not be affected severely since more and more German scientists prefer to publish in English journals. However, German researchers engaged in the fields of engineering and social sciences are still used to publishing their outcomes in German journals that are not sufficiently covered by the SCIE and the SSCI, which maybe results in underestimate. Economics and psychology in the social sciences are exceptions to this rule as the majority of publications contributed by German authors is already written in English.

In this study, the analysis covers four types of documents – “articles”, “letters”, “notes” and “reviews”, which could represent the scientific achievements. As to the countries and regions selected, industrialized countries include USA, Great Britain, Germany, Japan, France, Canada, Italy, Netherlands, Switzerland, Sweden and Finland, while threshold countries are focused on the BRICS countries – Brazil, Russia, India, China and South Africa. At the same time, EU-12 countries, the group of the 12 central and eastern European countries that have joined the European Union after 2004 and differ significantly from original EU-15 countries in terms of political and scientific environment conditions, and EU-15 as well as EU-27 countries as a whole are also observed in this report.

2.1 Whole vs. fractional counting

International collaboration in science and technology results in huge growth in international co-publications. Therefore another question has arisen which kind of methods of counting should be used while treating international collaborated papers, whole counting or fractional counting. In whole counting each country that makes contributions to the publication gets one credit for its participation. In fractional counting a country is credited a fraction of a publication in terms of its share of number of participating countries.[1] For instance, if an article was written by a German and two USA authors, Germany is allocated a count of 1/3, and USA is

1 Other variances of this counting method use the number of participating authors or institutes to calculate the fraction that is assigned to each country accordingly.

allocated a count of 2/3; if three authors come from three countries, then each country is allocated 1/3 of a paper; and so on. It is easy to find that from a mathematical perspective, the sum of the country shares is equivalent to the total number of publications for a fractional counting, while the former is inflationary for a whole counting.

Table 1 displays the comparison of share of publication for the selected countries in 2011 according to whole and fractional counting. It is obvious that using fractional counting almost invariably results in a lower share of publications for a country as only proportions of internationally-collaborative publications are counted. The difference between whole and fractional counting is generally greatest for the countries with the highest proportion of international co-publications. However, it is also showed that methods of counting don't change the number of country rankings in terms of the share of publication. On the other hand, it can be assumed that international co-publications, entailing considerable efforts to coordinate with foreign colleagues by overcoming geographic obstacles as well as barriers caused by different scientific policy, culture and history, deserve a higher weight than national co-publications as well as single-authored publications. So the fractional counting of publication may undervalue the credits of internationally collaborated publications. As a result, this analysis is primarily based on whole counting, which is also in correspondence with the views of the federal German government formulated in the internationalization strategy (BMBF 2008), to achieve inspiration through cooperation with the international elite.

Table 1: Share of selected countries within all SSCI and SCIE publications of 2010 according to fractional and whole counting

				Ranking	
	Whole count	**Fractional**	**Whole/Fractional**	**Whole count**	**Fractional**
USA	28.0	23.9	1.2	1	1
Japan	6.0	5.2	1.1	5	5
Germany	7.2	5.2	1.4	4	4
Great Britain	7.8	5.7	1.4	3	3
France	5.2	3.8	1.4	6	6
Switzerland	1.8	1.1	1.7	13	13
Canada	4.5	3.3	1.4	7	7
Sweden	1.6	1.1	1.5	14	14
Italy	4.3	3.3	1.3	8	8
Netherlands	2.6	1.8	1.5	12	12
Finland	0.8	0.6	1.5	15	15
South Korea	3.3	2.9	1.1	10	10
Brazil	2.6	2.3	1.1	11	11
India	3.5	3.1	1.1	9	9
China	10.9	9.8	1.1	2	2
Other countries	36.0	27.1	1.3		
Total	122,5	100,0			

Source: Web of Science, searches and calculations by Fraunhofer ISI.

2.2 Inclusion vs. exclusion of self-citations

Another methodological question is related to self-citation, which refers to an author, institution, country or journal citing its own publications. In this report, we only consider author self-citation. The question whether citation analysis should include self-citation or not has been raised for years (Costas et al. 2010; Glänzel et al. 2004). The arguments in favour of including self-citations are that self-citations at the macro level do not represent a major problem and constitute a natural part of the communication process especially in a new field. Furthermore, excluding self-citations would eliminate many relevant citations if many co-authors contributed to a publication. The arguments against self-citation are that self-citations do not specifically show the scientific impact of publications and that different self-citation patterns have been explored in different countries and regions. As it is noted that the external citations are the most relevant for evaluative purpose, this study follows the recommendation of CWTC to exclude self-citation.

2.3 Share of publications and share of citations

The share of publications for countries and regions are considered besides the absolute number of publications when an international comparison is made due to an obviously and continually increasing number of publication in peer-reviewed journals indexed in the SCIE and the SSCI database (Larsen/von Ins 2010).

Apart from the number of publications, citations received are further observed as a bibliometric indicator of impact of papers because counting of publication is treating all publication alike without regard to their widely different values (Larsen/von Ins 2010). Many scientists have compared the length of citation windows in various fields, and concluded that in science these usually peak or reach a level close to the highest score in the 3rd year after publication (Nederhof AJ 2006). On the other hand, it is noted that citations obtained in early years are found to be a good predictor for those obtained in total (Adams 2005). Therefore a three-year citation window, which balances precision with timeliness mostly (Wang 2012), is acceptable to estimate the scientific impact of publications in this study though it is surely not as precise as citation window of five years that is used in some other studies. As a result, here citation count is based on a three-year citation window, i.e. the number of citations received during the first three years after publication date are counted, the year of publication being included. In this study all indicators based on citation counts were only calculated for those publications published in or before 2009.

2.4 Scientific Regard (SR)

It is well-known that citation practices vary greatly across disciplines. For example, the average number of citations received per publication in biotechnology is much higher than that in mathematics. In order to solve the problem, an approach to normalization for field differences was introduced by the Dutch research group CWTS (Centre for Science and Technology Studies) in Leiden, i.e. field- or discipline-specific standardization, which is also called "Crown indicator". The field-specific average value is determined by calculating the average citation rate for all publications in journals belonging to the field of the publication considered (Van Raan 2004). Though it undoubtedly shows a substantial progress comparing with the pure citation rate, this field-specific standardization ignores the fact that the database of Thomson Reuters primarily covers American publications and that they gain especially high citation rates due to the broad readership and good visibility of American journals.

Also, this field-specific standardization does not take into account that the databases cover a lot of small and specialized journals, which certainly have smaller readership, and lower visibility and citation rate than big and mainstream journals (Michels/Schmoch 2011). Furthermore, a single field comprises more or less subfields with completely diverse citation practices, so it is questionable whether fields can be considered as homogeneous entities. Consequently, the feasibility of using field-specific average as normalization for field differences is unclear.

Against this background, Fraunhofer ISI has used journal-specific expected citation rates for the reports on the technological competitiveness of Germany commissioned by the BMBF and the Commission of Experts on Research and Evaluation (EFI) (Achleitner et al. 2008; Grupp et al. 2001; Schmoch/Qu 2009). If the observed average citation rate of a country is equivalent to the journal-specific expected citation rate, resulting from the average citation rate of journals in which the country's authors published their papers, it means a neutral value of one; value above one implies that the citation rate of a country is above average; value below one implies that the citation rate of a country is below average. However, theoretically speaking the range of values will be between 0 and + ∞, which is little illustrative for graphics and interpretation. Then a transformation method is used, where the range of value is between -100 and +100, positive values of this index show above-average citation rates; negative values of this index show below-average citation rates; values of 0 is regarded equivalent to the average. So, the derived indictor "Scientific Regard" (SR) can describe whether the publications of a country/region are cited above average or below average, compared to other publications in the same journals where the observed papers appear. It is obvious that the reference values for publications in non-American journals, especially non-English journals as well as small journals are relatively lower, while those in highly visible journals are relatively higher. The SR value is calculated as follows:

$$SR_k = 100 \tanh \ln (OBS_k/EXP_k)$$

Where OBS_k denotes the actual observed citation frequency of publications of country k. EXP_k denotes the expected citation rate resulting from the average citation frequency of the journals where the authors of this country published their papers.

2.5 International Alignment (IA)

Another indicator "International Alignment (IA)" describes whether the authors of a country release their achievements in internationally more or less visible journals, compared to the world average. In general, a country's high share of publications in internationally visible journals implies its intensive and active participation in knowledge creation, diffusion, exchange and sharing. Similarly to the SR index, positive IA values mean the impact of journals carrying observed publications is higher than the world average, vice versa; values of 0 indicate equivalence to the world average. The IA value is calculated as follows:

$$IA_k = 100 \tanh \ln (EXP_k/OBS_w)$$

Here OBS_w denotes the actual observed citation rate of all publications in the world. EXP_k denotes the expected citation rate of the journals where the authors of this country published their papers.

On all accounts, journal-specific based citation indices including SR and IA lead to better analyses of high citation rate. It becomes possible to inspect whether they are based on scientifically valuable publications, or on a good ranking of a publication, or the placement of a publication in a high impact journal.

2.6 Revealed Literature Advantage (RLA)

In addition to the aggregate data of the countries observed, the publication activities in different fields are inspected based on a specialization index, a comparison of the share of publications by country in a specific field with the share of this field within all worldwide publications. This so-called RLA index (RLA = Revealed Literature Advantage) is calculated as follows:

$$RLAij = 100 \tanh \ln [(Publij / \Sigma i\ Publij) / (\Sigma j\ Publij / \Sigma ij\ Publij)]$$

Here i denotes the country and j the field. Similarly to the SR and IA index, positive values mean a positive specialization compared with the world average, negative ones a specialization below average.

2.7 Co-publications

For this part of the study as well, the publications were counted whole-count, as this is the more appropriate counting metric when co-publications are to be analyzed. By using whole-count, all publications that are associated with a country are counted as 1 publication for this country, independent of the number of co-authors from other countries (see above). In contrast to that, fractional count assigns values less then 1 for publications with authors from other countries. The exact calculation method depends on the basic units (cf. Gauffriau et al. 2008), but all have in common that a publication has less weight for each country the more different countries in total are involved. Therefore, a fractional count would not be feasible for the analysis of co-publications, since the number of co-publications can only be counted as whole.

The citation numbers for publications in the years 2011 and later decrease because of (yet) incomplete database coverage. To get a concise overall picture, we therefore restrict our analysis to the years 2000 to 2010.

A co-publication of Germany with any other country is counted when a publication was written by at least one author with a German affiliation and one author with a foreign affiliation. Since the Web of Science only offers the option to map a publication to an author and this author to a so-called research address, a co-publication might also be counted for authors for whom there are multiple affiliations on hand. It would be possible to identify these authors, but there is no option to decide which of their affiliations should be assigned and why. Therefore, we count these collaborations similar to actual co-publications since it can be assumed that both addresses contributed in their own way to the publication.

The field definition is based on an internal mapping of the 247 journal categories in the Web of Science to 27 aggregating fields of science. Thomson Reuters assigned multiple categories to most of the journals, so that an article might end up in up to 10 categories. The field aggregation partly weakens this effect by subsuming various categories in one field, but still journals and therefore articles might be assigned to more than one field.

2.8 Social Network Analysis

A Social Network Analysis (SNA) was conducted on the co-publication data. An undirected network is constructed from this data, assuming that the knowledge flow between two collaborating countries is not directed, i.e. knowledge is shared in equal parts in any co-publication. This might be a general assumption that might not hold in every case, but we have to presume that every part in a collaboration would benefit from said act since otherwise they would not participate. Thus, an undirected graph seems to be the best means to represent co-publications as a form of collaboration. The nodes in this graph represent the countries, while the edges between two nodes represent co-publications of the respective two countries. Thus, a co-publication that involves more than two countries is represented by connections between all possible pairs of actors involved in the respective publication.

In the SNA, we used different metrics to interpret the role of the specific countries in the network. The first applied metric from Network Analysis is betweenness centrality, which belongs to the group of centrality measures. Centrality measures are essential tools for the analyses of social networks, which are designed to rank the actors of a network according to their position within the network or in other words, to find the actors that are most "central" to the network (Bavelas 1948; Freeman 1979; Sabidussi 1966). The basic idea behind the betweenness centrality now is that a node within a network is important if it lies on a high share of "shortest paths" within the network. Maybe it is more illustrative to think of it as the amount of traffic that flows through a node due to its connection to several different actors. If the traffic that passes this node is high, it has an increased importance for the whole system. Formally, the betweenness centrality is defined as (Brandes 2001; Freeman 1977):

$$C_B(v) = \sum_{s \neq v \neq t \epsilon V} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

where V is the total number of nodes or actors within the system, s and t are the starting and the end point of a path, and $\sigma_{st}(v)$ is the number of shortest paths from s to t that some $v \in V$ lies on.

The second measure that will be used in the following analyses is the measure of modularity, which is used to detect communities – sets of highly interconnected nodes (Fortunato/Castellano 2009) – within a network. In other words, the network is divided into two or more clusters or partitions. Within these partitions, the individual nodes (or group members) have stronger relationships to each other than to the members of the other group as shown by the larger number of mutual connections (Fortunato/Castellano 2009).

In general, the modularity of a partition can take on values between −1 and 1, measuring the density of links inside communities as compared to links between communities (Blondel et al. 2008; Newman 2006; Newman/Girvan 2004). In the case of weighted networks (in our case the number of co-patents between two countries serve as weights), the modularity is defined as (Newman 2004):

$$Q = \frac{1}{2m}\sum_{i,j}\left[A_{i,j} - \frac{k_i k_j}{2m}\right]\delta(c_i, c_j)$$

where $A_{i,j}$ represents the weight of the edge between i and j, $k_i = \sum_j A_{ij}$ is the sum of the weights of the edges attached to vertex i, c_i is the community to which vertex i is assigned, the δ function $\delta(u, v)$ is 1 if $(u = v)$ and 0 otherwise and $m = \frac{1}{2}\sum_{ij} A_{ij}$.

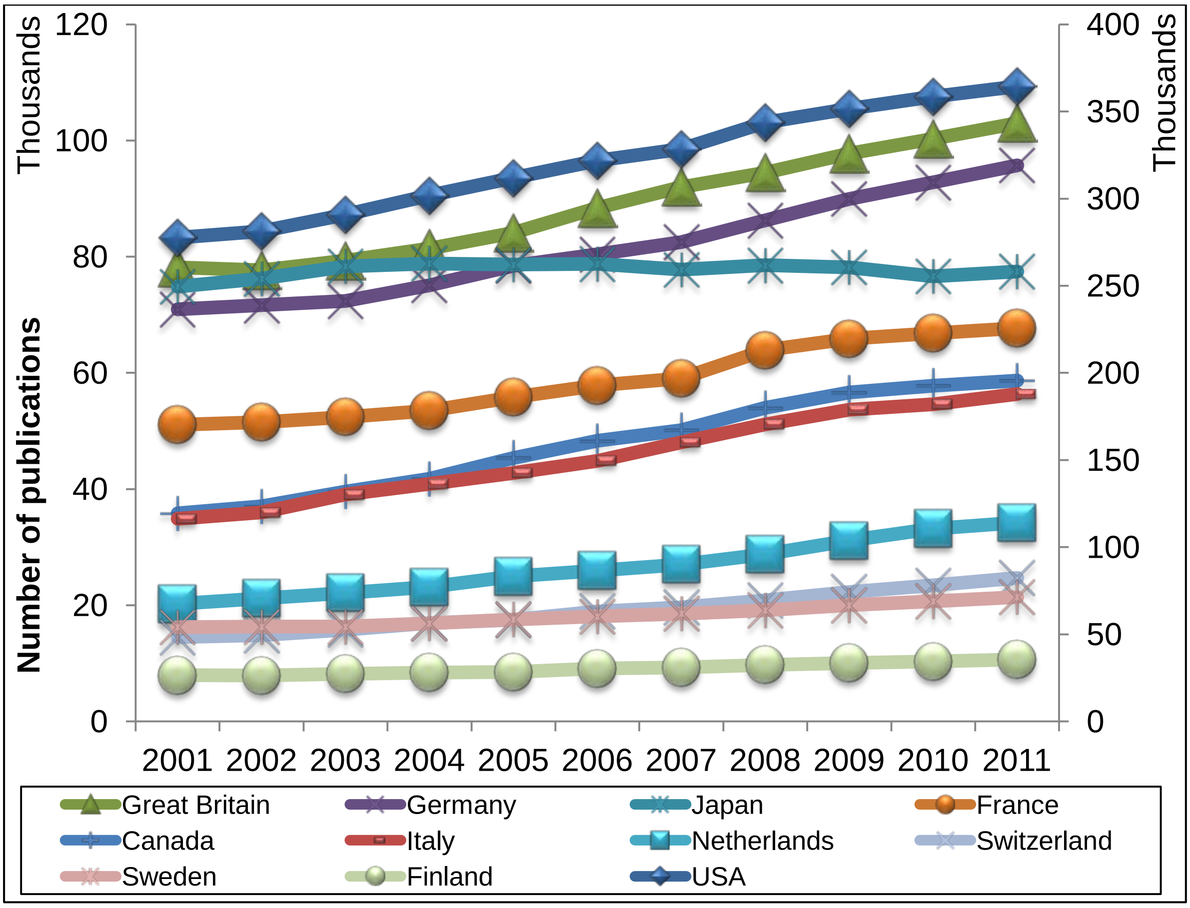
However, since exact modularity optimization is a problem that is computationally hard, we use an approximation of modularity proposed by Blondel et al. (2008).

3. Publication in an international comparison

3.1 Number of publications

Figure 1 and Figure 2 display the absolute number of publications of selected industrialized countries and the BRICS countries respectively from 2001 to 2011. Due to USA's higher publication output, two different y-axes are used in Figure 1 in order to gain an easier comparison of trends between countries with markedly different publication counts. The publication numbers of all countries show continuously increasing trends in the latest decade except Japan and Russia, which experienced diversely up and down trends with the lowest compound annual growth rate (CAGR) of 0.35 and 1.04% respectively.

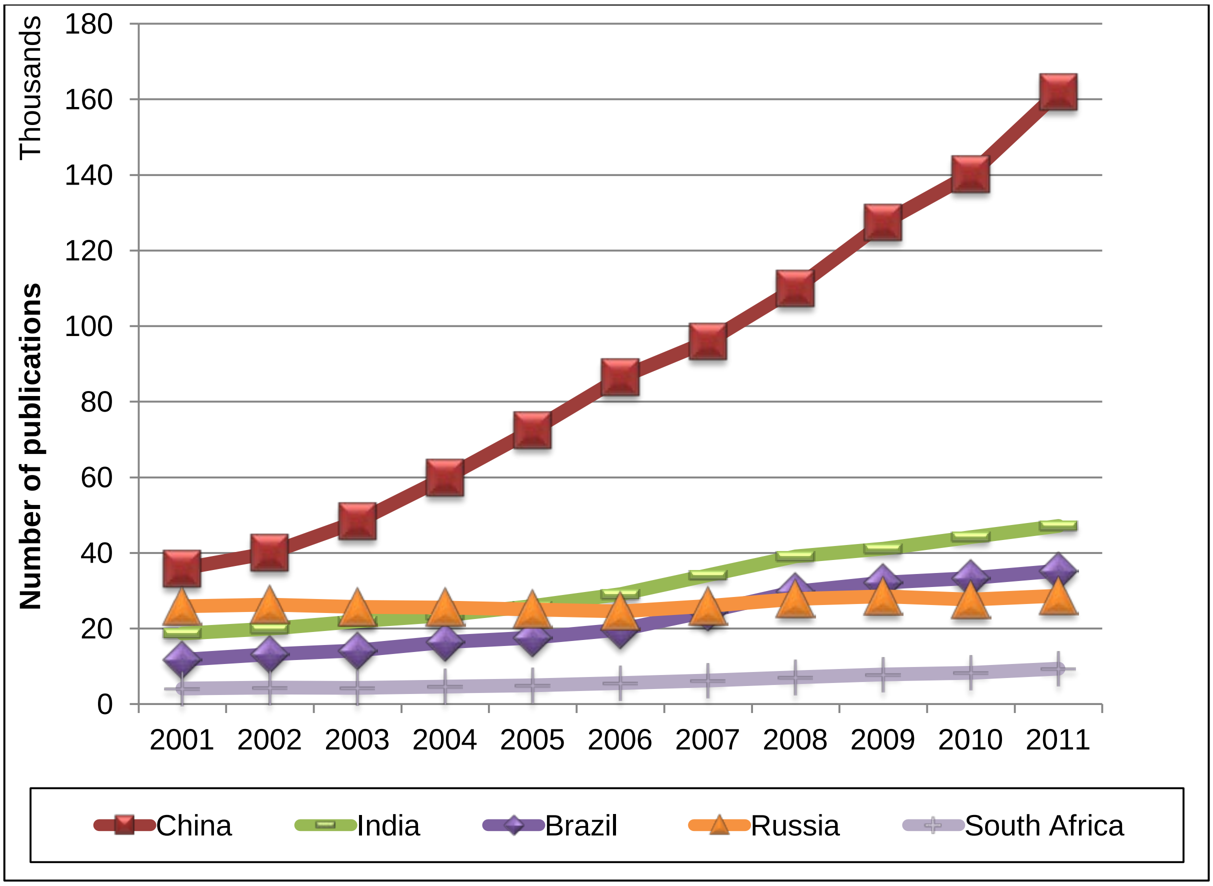
Figure 1: Publication number of selected industrialized countries in the SCIE and the SSCI (whole counts)



Source: Web of Science, searches and calculations by Fraunhofer ISI.

Germany ranks fourth in terms of the number of publication over the whole observation period with a CAGR value of 3.04%, which is slightly higher than Great Britain with 2.80%. Among industrialized countries, Switzerland and Netherland have the highest CAGR values of about 5.40%; while it is China and Brazil among BRICS, with the highest CAGR figures of 16.28 and 11.58%.

Figure 2: Publication number of the BRICS countries in the SCIE and the SSCI (whole counts)



Source: Web of Science, searches and calculations by Fraunhofer ISI.

As shown in Table 2, when the publication number of a country in the year 2001 is set to 100, the index for Germany in the year 2011 is 135. There are various patterns of trends in the publication activity in 16 selected countries over time. The table shows the fastest growing indices in threshold countries, including China, Brazil, India and South Africa, with indices of 227 to 452. Sharp growth occurs in those countries firstly due to their comparatively small publication base; on the other hand, the increasing investments in science and technology should also be responsible for the developments. Russia is an exception among the BRICS countries with an index of 111 in 2011 that is much below the world average, partly due to the fact that most Russian scientists publish and communicate in their mother tongue and have developed a relative independent scientific community apart from other countries.

Furthermore, continual growth that is slightly above the world average could be observed in Canada, Netherlands, Italy and Switzerland, with indices of 162 to 170. At the same time their percentage shares of total publication, which all are less than 4.5%, are noticed. On the other hand, the opposite is shown in USA, Germany, Great Britain, France, Finland and Sweden. Their indices for 2011 are between 131 and 135. On the lowest level, in Japan the increase is lowest in the last years with an index of 104.

EU-12 countries, joining EU formally after 2004, have shown a notably rising trend before 2008, which is very similar to South Africa. Especially between 2006 and 2008 their CAGR value impressively reached to 13.35%. However, the EU-12 growth rate of publication has remained considerably decreasing compared with the world average rate since 2008.

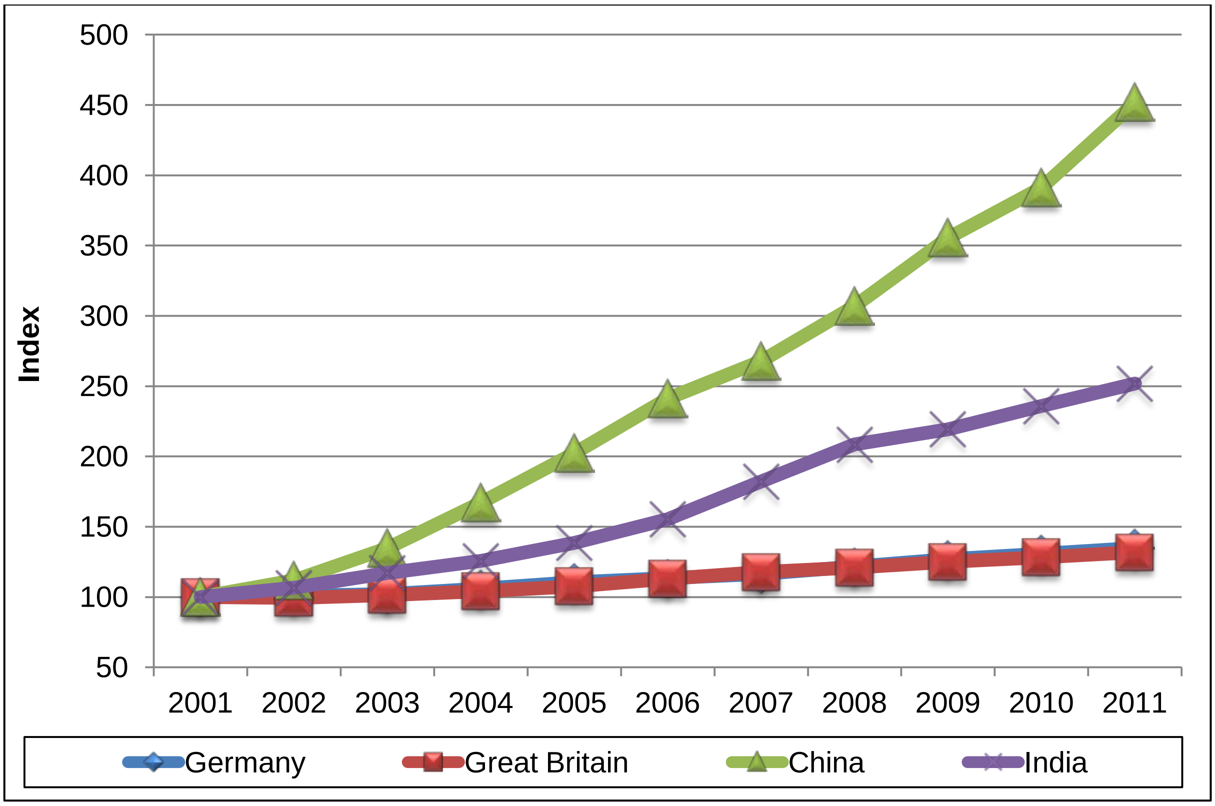
Table 2: Development of the publication number of selected countries and regions in the SCIE and the SSCI (whole counts. Index 2001=100)

Country/region	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
USA	100	101	105	109	112	116	118	124	127	129	131
Great Britain	100	99	101	104	108	113	118	121	125	128	132
Germany	100	101	102	106	111	113	116	122	127	131	135
Japan	100	102	105	105	105	105	104	105	104	102	104
France	100	101	103	105	109	113	116	125	129	131	133
Canada	100	103	111	117	127	135	140	151	158	161	164
Italy	100	103	112	117	123	129	138	147	154	157	162
Netherlands	100	105	109	114	123	128	134	142	154	164	169
Switzerland	100	102	109	117	121	130	135	144	154	162	170
Sweden	100	101	101	104	108	111	114	118	123	128	132
Finland	100	99	103	106	107	115	117	122	127	130	134
China	100	112	135	167	202	241	268	307	355	391	452
India	100	107	117	126	139	155	182	209	219	236	252
Brazil	100	112	120	140	149	167	208	253	273	283	299
Russia	100	102	99	99	97	95	100	108	110	107	111
South Africa	100	106	104	113	120	135	151	172	190	201	227
EU-15 countries	100	101	104	108	112	117	121	128	133	136	140
EU-12 countries	100	104	111	119	123	134	152	172	179	184	190
EU-27 countries	100	101	105	108	113	118	123	131	136	139	144
World	100	102	106	111	116	122	128	137	143	147	153

Source: Web of Science, searches and calculations by Fraunhofer ISI.

The development in publication numbers is also illustrated for four selected countries in Figure 3. Germany and Great Britain were further analysed as representatives of industrial countries since they have similar shares of publication, as well as even similar level of GDP per capita. However, Germany has its own language that only predominates in European area, but not worldwide as English does. At the same time, China and India, two emerging countries, were also chosen for further analysis as they are the two most populous nations in the world and the most publishing nations among developing countries. However, both have major differences in terms of innovation systems, strategic emphasis as well as historical and cultural background.

Figure 3: Development of the publication number of four selected countries in the SCIE and the SSCI (whole counts. Index 2001=100)



Source: Web of Science, searches and calculations by Fraunhofer ISI.

As shown in Figure 3, both Germany and Great Britain experienced an equal moderately increasing trend from the beginning of the new century. British authors published about 0.5% more publications retrieved from the SCIE and the SSCI in 2011 than Germany largely due to the database's preference for English-language journals that have higher international visibility and in consequence higher values provided by the Journal Citation Reports (JCR), which is the primary criterion for evaluating and choosing journals indexed in the databases. During the same period, the numbers of publications released by Chinese authors go up constantly at a remarkable speed, as does India until 2008.

3.2 Share of publications

Despite the countries' similar growth in absolute numbers, their shares in worldwide publications develop dissimilarly. The shares of selected countries and regions within all publications are presented in Table 3, where it can be seen that Germany's share has reduced slowly but continuously, from 8.2 to 7.2% during the past decade. Similar decreases in percentage also can be found in other industrialized countries including USA, Japan, Great Britain, and so on, which mostly results from the dramatic growth of publications contributed by those threshold countries, first of all China.

Table 3: Shares of selected countries and regions in the SCIE and the SSCI within all publications (whole counts)

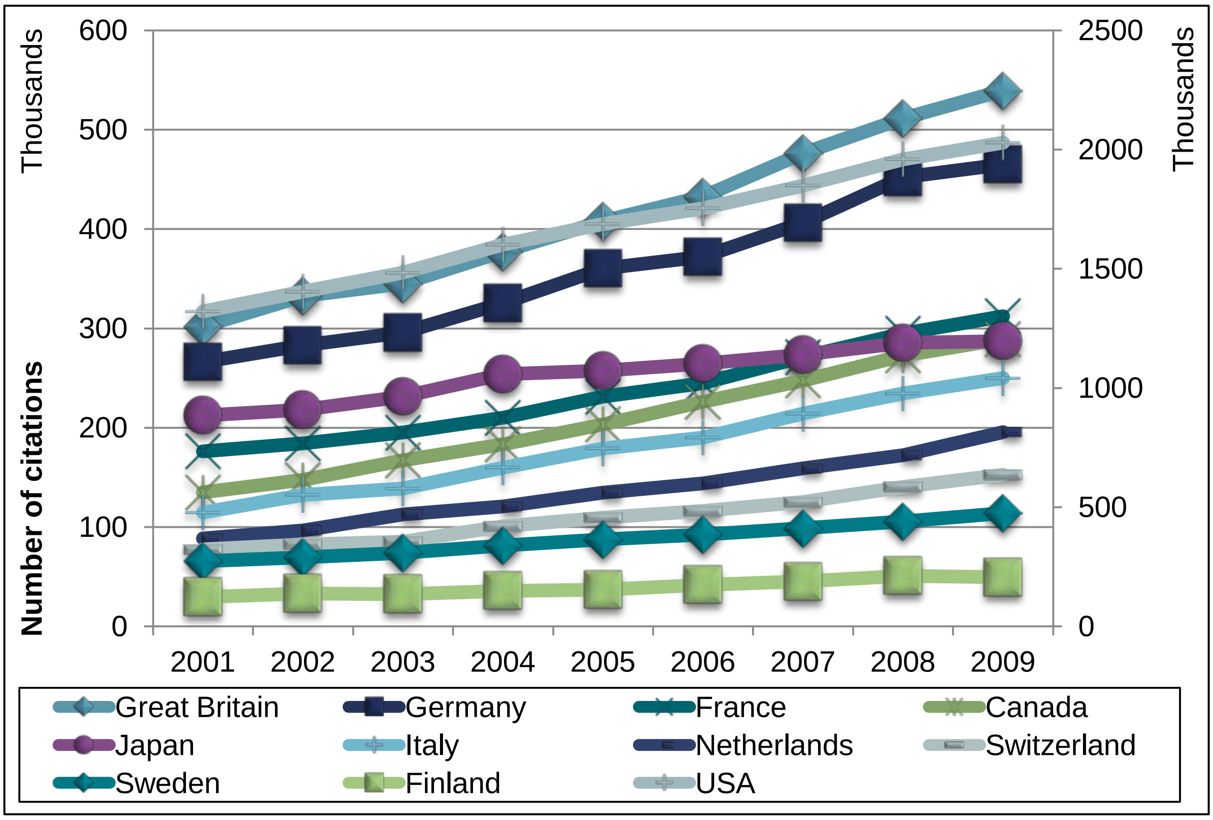
Country/region	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
USA	31.9	31.7	31.5	31.3	30.8	30.3	29.4	28.7	28.2	28.0	27.4
Great Britain	9.0	8.7	8.6	8.4	8.3	8.3	8.2	7.9	7.8	7.8	7.7
Germany	8.2	8.1	7.8	7.8	7.7	7.6	7.4	7.2	7.2	7.2	7.2
Japan	8.6	8.6	8.5	8.2	7.8	7.4	7.0	6.6	6.3	6.0	5.8
France	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.3	5.3	5.2	5.1
Canada	4.1	4.2	4.3	4.3	4.5	4.5	4.5	4.5	4.5	4.5	4.4
Italy	4.0	4.1	4.2	4.2	4.2	4.2	4.3	4.3	4.3	4.3	4.2
Netherlands	2.3	2.4	2.4	2.4	2.5	2.4	2.4	2.4	2.5	2.6	2.6
Switzerland	1.7	1.7	1.7	1.8	1.7	1.8	1.8	1.7	1.8	1.8	1.9
Sweden	1.9	1.8	1.8	1.8	1.7	1.7	1.7	1.6	1.6	1.6	1.6
Finland	0.9	0.9	0.9	0.9	0.8	0.9	0.8	0.8	0.8	0.8	0.8
China	4.1	4.5	5.2	6.2	7.2	8.1	8.6	9.2	10.2	10.9	12.2
India	2.2	2.2	2.4	2.4	2.6	2.7	3.1	3.3	3.3	3.5	3.5
Brazil	1.4	1.5	1.5	1.7	1.7	1.9	2.2	2.5	2.6	2.6	2.7
Russia	3.0	3.0	2.8	2.7	2.5	2.3	2.3	2.3	2.3	2.2	2.2
South Africa	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7
EU-15 countries	35.0	34.8	34.3	34.0	33.8	33.6	33.1	32.6	32.5	32.3	32.0
EU-12 countries	3.3	3.3	3.4	3.5	3.4	3.6	3.9	4.1	4.1	4.1	4.0
EU-27 countries	37.4	37.2	36.8	36.5	36.2	36.2	36.0	35.7	35.5	35.4	35.1
World	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Web of Science, searches and calculations by Fraunhofer ISI.

3.3 Number of citations

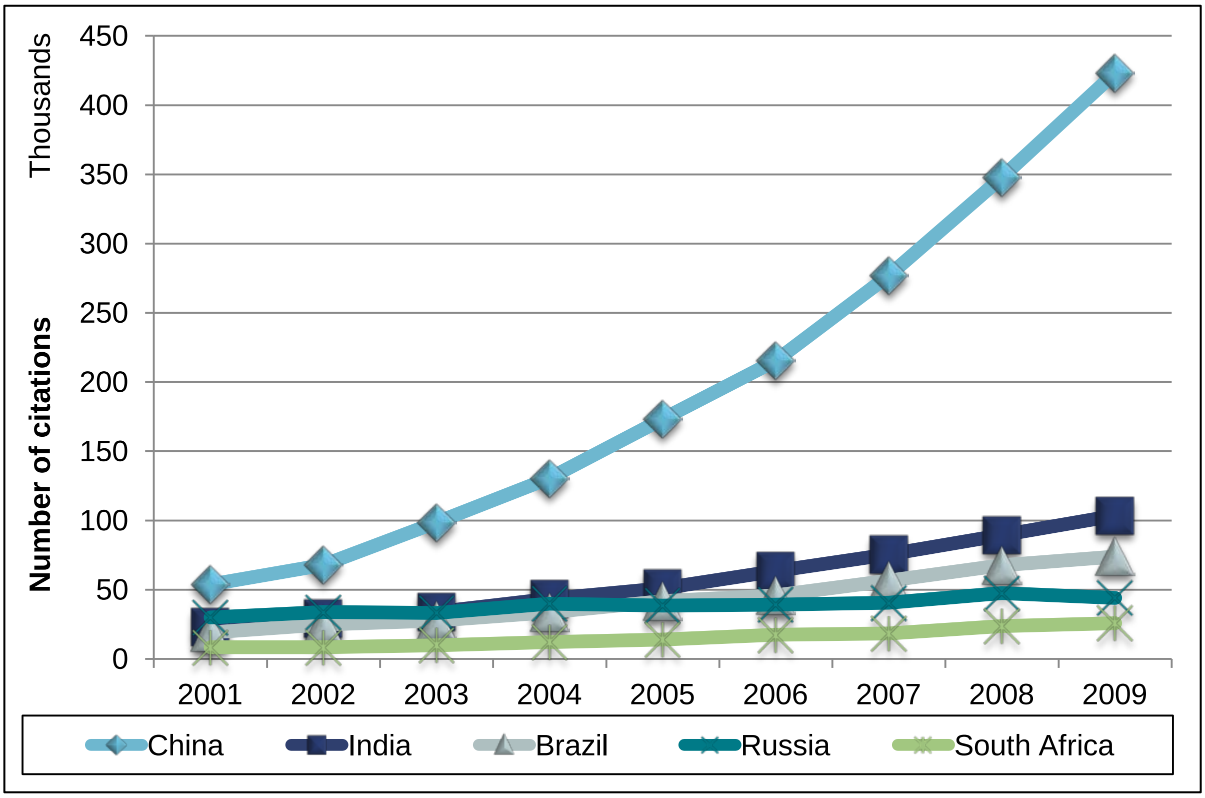
As shown in Figure 4 and Figure 5, the absolute numbers of citations in all countries and regions show increasing trends. This follows not only from the overall growing number of publications but also from the sustained growth of the number of references per paper in all fields (Larsen/von Ins 2010) which in turn leads to an increased number of journals indexed in SCIE and SSCI.

Figure 4: Citation numbers of selected industrialized countries in the SCIE and the SSCI



Source: Web of Science, searches and calculations by Fraunhofer ISI.

Figure 5: Citation numbers of BRICS countries in the SCIE and the SSCI



Source: Web of Science, searches and calculations by Fraunhofer ISI.

3.4 Share of citations

Table 4 shows the changes of citation shares of selected countries and regions. It can be found that the time trends based on the shares of citations were in accordance with that of the shares of publications. USA-authored papers are cited most, accounting for 42.9% of all citations in 2011, about 14.6% higher than its percentage of all publications (Figure 6). It is followed by Great Britain and Germany, with differences between shares of publications and shares of citations of 3.5 and 2.6% respectively. The above-mentioned countries have kept a comparably stable performance according to their ranks, and Germany always ranked third in the world. However, it was obvious that Germany's share in 2009 decreased compared with previous years.

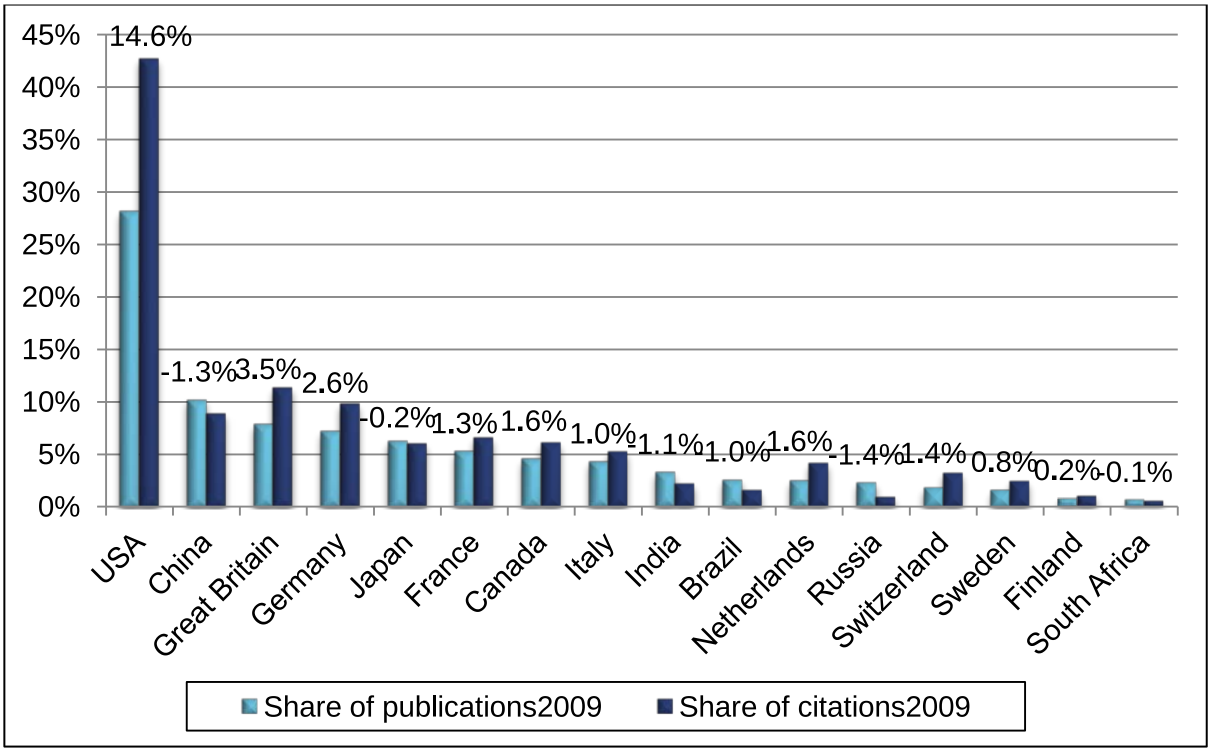
Table 4: Shares of selected countries and regions in the SCIE and the SSCI within all citations

Country/region	2001	2002	2003	2004	2005	2006	2007	2008	2009
USA	50.9	50.4	49.3	48.5	47.1	45.9	44.6	43.8	42.7
Great Britain	11.6	11.9	11.5	11.4	11.4	11.3	11.5	11.4	11.4
Germany	10.3	10.1	9.8	9.9	10.1	9.7	9.8	10.1	9.8
Japan	8.2	7.8	7.7	7.7	7.2	6.9	6.6	6.4	6.0
France	6.8	6.6	6.5	6.4	6.5	6.4	6.5	6.6	6.6
Canada	5.2	5.3	5.6	5.6	5.7	5.9	6.0	6.1	6.1
Italy	4.4	4.8	4.6	4.8	5.0	5.0	5.2	5.2	5.3
Netherlands	3.4	3.5	3.8	3.7	3.8	3.8	3.8	3.9	4.1
Switzerland	3.0	3.0	2.8	3.1	3.1	3.0	3.0	3.1	3.2
Sweden	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4
Finland	1.1	1.2	1.1	1.1	1.0	1.1	1.1	1.1	1.0
China	2.1	2.4	3.3	4.0	4.8	5.6	6.7	7.8	8.9
India	0.9	1.0	1.1	1.3	1.4	1.7	1.8	2.0	2.2
Brazil	0.7	0.9	0.9	1.0	1.2	1.2	1.4	1.5	1.6
Russia	1.2	1.2	1.1	1.2	1.1	1.0	1.0	1.1	0.9
South Africa	0.3	0.3	0.3	0.4	0.4	0.5	0.4	0.5	0.5
EU-15 countries	39.0	39.1	38.7	38.5	38.9	38.6	38.7	38.7	38.5
EU-12 countries	1.9	2.0	2.1	2.3	2.3	2.5	2.6	2.6	2.7
EU-27 countries	40.0	40.1	39.8	39.6	40.0	39.9	40.1	40.0	39.9
World	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Web of Science, searches and calculations by Fraunhofer ISI.

On the other hand, it also can be observed that China is in the opposite way, receiving 8.9% of citations with 12.2% of publications though it has increased its share of citations steadily year by year. Other BRICS countries as well as Japan seem to perform the similar way, like India and Brazil, about 1% difference between shares of papers and citations.

Figure 6: Comparison of share of publications and citations of 16 selected countries in the SCIE and the SSCI



Source: Web of Science, searches and calculations by Fraunhofer ISI.

3.5 Observed citation rate

When publication size is not taken into account, Switzerland and the Netherlands have remained a stable, excellent performance as well as the USA in terms of the observed citation rates (Table 5). However, the USA have slipped one spot to third place, with a a narrow margin to Sweden that was ranked fourth in 2009. It is noted that the EU-12 countries' share of total citations has not kept pace with its increasing publication share. This results in a low citation rate, which is only higher than that of Brazil and Russia - the former having steadily slipped in rank since 2005 and thus becoming the second-lowest ranked country, and the latter having always been the lowest ranked among the observed countries.

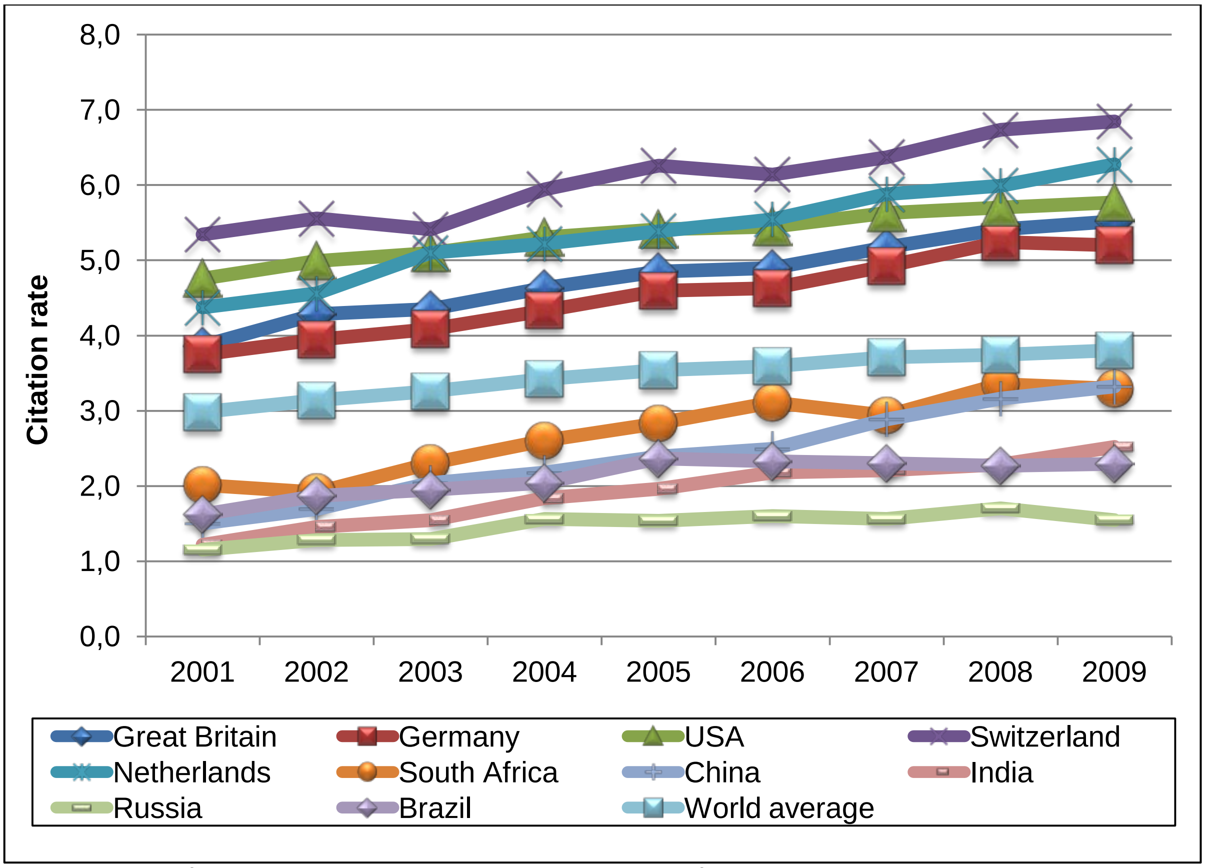
Table 5: Observed average citation rates for selected countries and regions in the SCIE and SSCI without self-citations

Country/region	2001	2002	2003	2004	2005	2006	2007	2008	2009
USA	4.8	5.0	5.1	5.3	5.4	5.4	5.6	5.7	5.8
Great Britain	3.9	4.3	4.4	4.6	4.9	4.9	5.2	5.4	5.5
Germany	3.7	3.9	4.1	4.3	4.6	4.6	4.9	5.2	5.2
Japan	2.8	2.9	3.0	3.2	3.3	3.4	3.5	3.6	3.7
France	3.5	3.6	3.7	3.9	4.1	4.2	4.6	4.6	4.7
Canada	3.8	4.0	4.2	4.4	4.5	4.7	4.9	5.0	5.1
Italy	3.3	3.7	3.6	3.9	4.2	4.2	4.5	4.6	4.7
Netherlands	4.4	4.6	5.1	5.2	5.4	5.5	5.9	6.0	6.3
Switzerland	5.3	5.6	5.4	5.9	6.3	6.1	6.4	6.7	6.8
Sweden	4.0	4.3	4.5	4.8	5.0	5.1	5.3	5.5	5.7
Finland	3.7	4.2	4.0	4.2	4.3	4.6	4.9	5.2	4.9
China	1.5	1.7	2.0	2.2	2.4	2.5	2.9	3.2	3.3
India	1.2	1.5	1.5	1.8	2.0	2.2	2.2	2.3	2.5
Brazil	1.6	1.9	1.9	2.0	2.4	2.3	2.3	2.3	2.3
Russia	1.15	1.28	1.29	1.56	1.54	1.60	1.56	1.70	1.55
South Africa	2.0	1.9	2.3	2.6	2.8	3.1	2.9	3.4	3.3
EU-15 countries	3.3	3.5	3.7	3.9	4.1	4.1	4.3	4.4	4.5
EU-12 countries	1.8	1.9	2.0	2.2	2.3	2.5	2.5	2.3	2.5
EU-27 countries	3.2	3.4	3.5	3.7	3.9	4.0	4.1	4.2	4.3
World	3.0	3.1	3.3	3.4	3.5	3.6	3.7	3.7	3.8

Source: Web of Science, searches and calculations by Fraunhofer ISI.

Again this indicator is illustrated by the data for four selected countries (Figure 7). Great Britain and Germany maintained a steadily upward trend and rank, and both countries increased beyond the world average level. Great Britain has always been somewhat higher also mostly due to the language bias mentioned above. Such bias could be strengthened because deserved attention to papers written in German has not been paid by researchers in the developing countries such as China and India due to language barrier, while the shares of those countries are continually increasing. On the other hand, China could not catch up with those countries with more advanced scientific development, and its scientific performance, i.e. the citation rate remains below the world average as all the other threshold countries and Japan do, though Chinese citation rate have been increased by a value of 2.21 during the past 10 years. Thus, China – as well as South Africa – rises to the BRICS' highest level, with a citation rate of 3.3. India increases its citation rates as well, but at a rather lower speed compared with China, and shows a relative stagnation since 2006.

Figure 7: Observed average citation rate for selected countries in the SCIE and the SSCI without self-citation

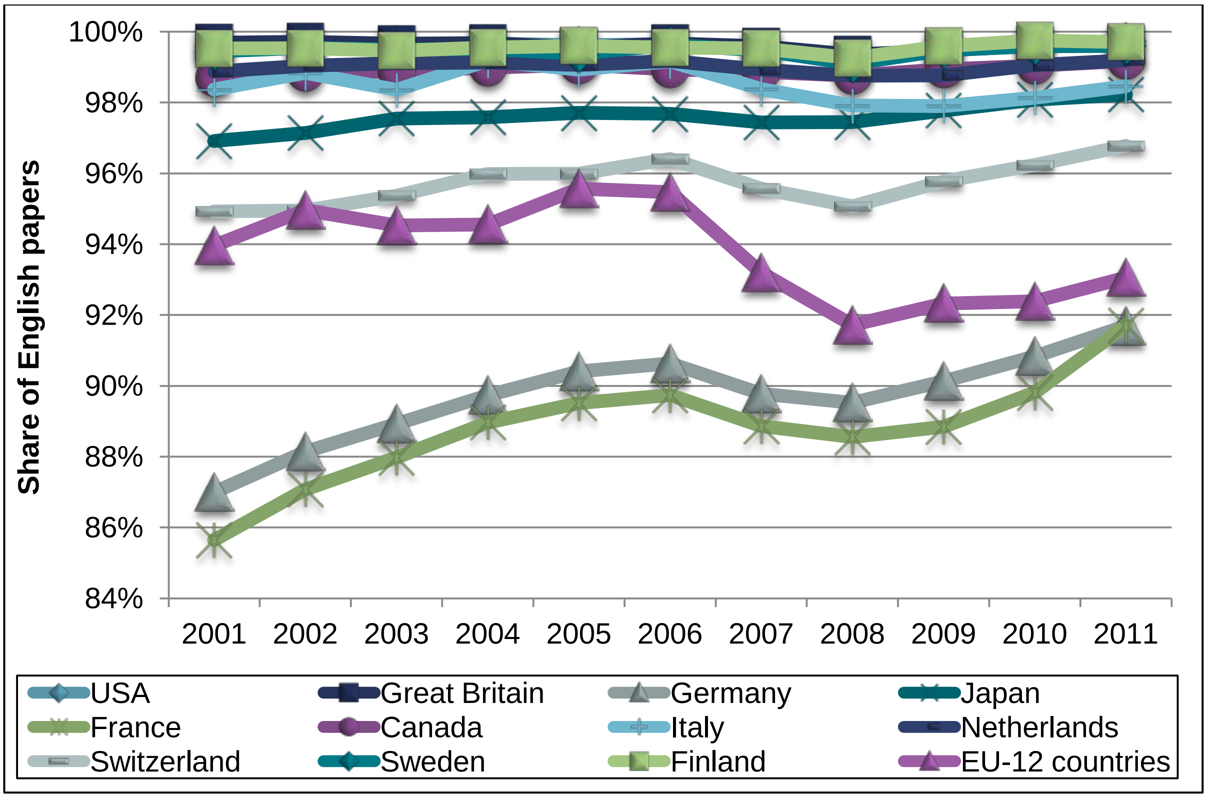


Source: Web of Science, searches and calculations by Fraunhofer ISI.

At the same time, it is noted that a language bias would affect the citation rate. The WoS data system also covers some journals in non-English languages, particularly in German and in French. Publications in these non-English language journals are counted as part of the output of countries, but they generally have a very low impact because only a few scientists outside Germany and France would possibly read and cite those papers. This is particularly the case for the more application-oriented fields such as clinical medicine and engineering, and also for the social sciences and humanities (Van Raan et al. 2011).

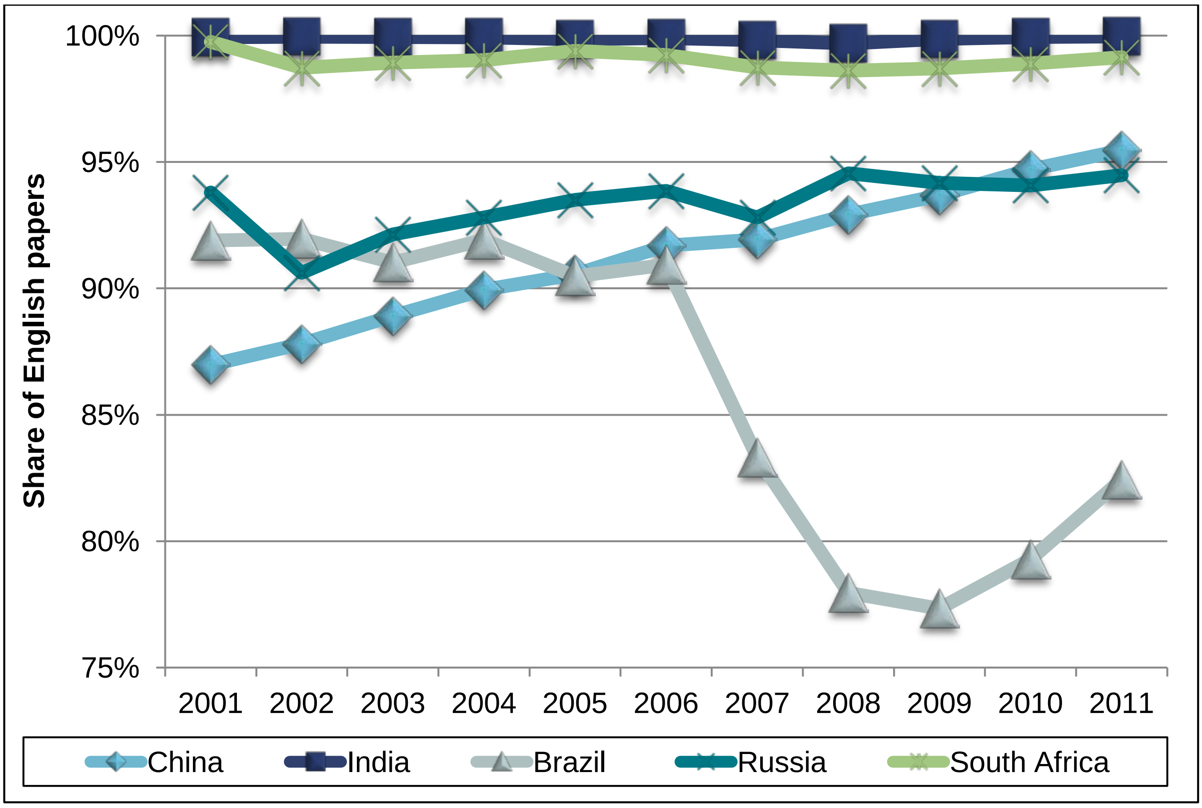
In this study, the effect of the language bias on the citation rate is also inspected. As shown in Figure 8 and Figure 9, the shares of English papers in countries vary greatly. In generally the shares of English papers is rather high, the level would be comparatively lower in those countries using their own languages, especially in Germany, France, Brazil, China and Russia, as well as EU-12 countries. However, their shares of English papers have remained an increasing trend in the last years. At the same time, an obvious decrease in shares of English publications could be found in Germany, France, Italy, Switzerland, EU-12 countries, and particularly in Brazil from 2007 to 2009, which mostly resulted from the extensive coverage of regional journals by the SCIE and the SSCI during the same period.

Figure 8: Share of English papers for selected industrialized countries in the SCIE and the SSCI



Source: Web of Science, searches and calculations by Fraunhofer ISI.

Figure 9: Share of English papers for BRICS countries in the SCIE and the SSCI



Source: Web of Science, searches and calculations by Fraunhofer ISI.

It could be found that the differences between citations rates of English papers and all papers are the largest in Germany, France and Brazil, about 0.5, implying the countries that are affected most by the language bias (Table 6). On the other hand, the increasing gap between both kinds of citation rates for Brazil since 2007 is maybe caused by the higher coverage of Brazilian regional journals in the WoS databases since then, which led to a growth in publication numbers with comparatively less citation counts. At the same time, Switzerland and China are also affected moderately by the language bias.

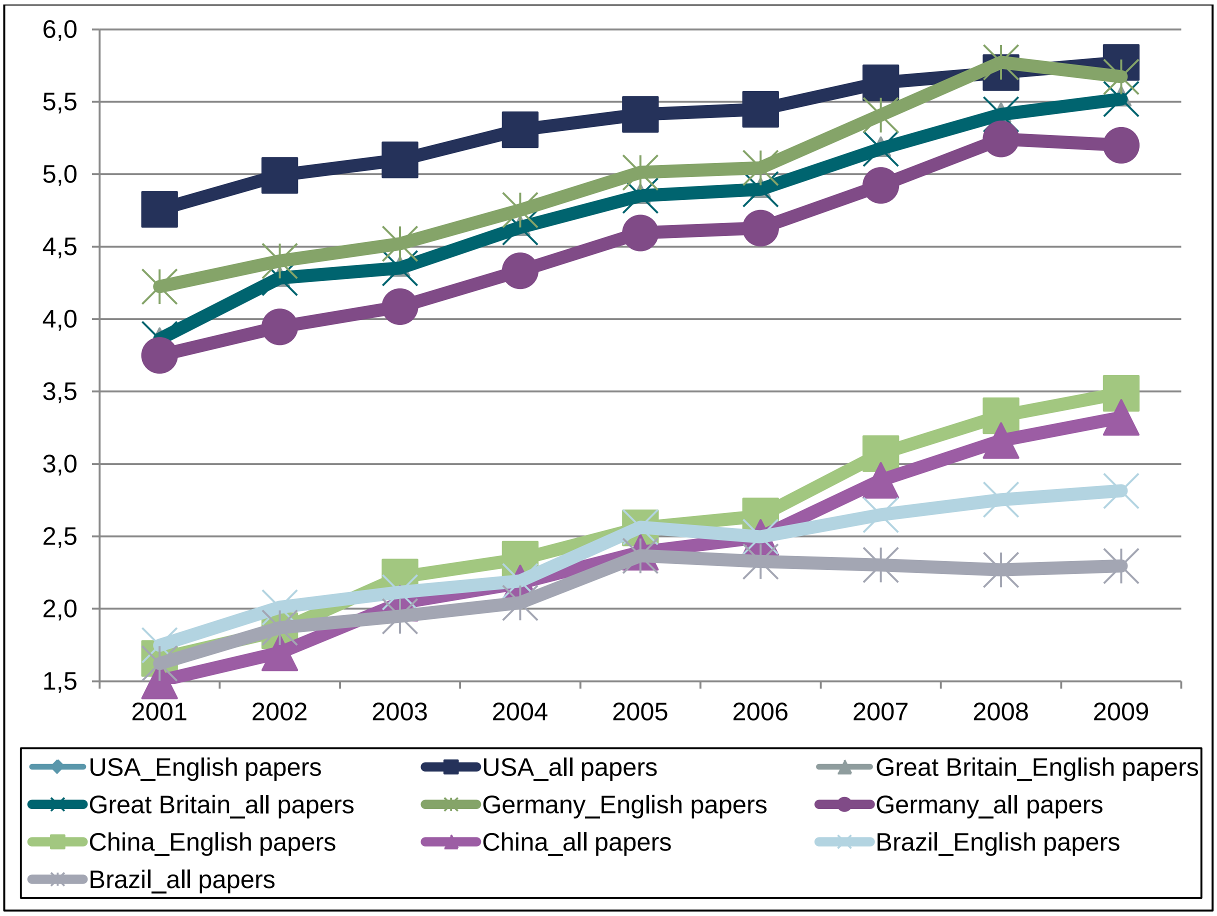
Table 6: Difference between citation rates of English papers and all papers for selected countries and regions in the SCIE and SSCI without self-citations

Country/region	2001	2002	2003	2004	2005	2006	2007	2008	2009
USA	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.02
Great Britain	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Germany	0.47	0.45	0.43	0.42	0.42	0.42	0.49	0.53	0.47
Japan	0.08	0.08	0.07	0.07	0.07	0.07	0.08	0.07	0.07
France	0.52	0.48	0.45	0.43	0.43	0.43	0.51	0.51	0.54
Canada	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.05
Italy	0.05	0.04	0.06	0.03	0.04	0.03	0.07	0.07	0.09
Netherlands	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.04	0.07
Switzerland	0.25	0.27	0.24	0.22	0.23	0.20	0.26	0.29	0.27
Sweden	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
Finland	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
China	0.15	0.15	0.18	0.16	0.17	0.15	0.18	0.17	0.17
India	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brazil	0.13	0.14	0.17	0.15	0.20	0.17	0.35	0.49	0.52
Russia	0.06	0.12	0.10	0.11	0.10	0.09	0.11	0.08	0.09
South Africa	0.00	0.02	0.02	0.02	0.02	0.01	0.03	0.04	0.04
EU-15 countries	0.21	0.20	0.19	0.18	0.18	0.18	0.22	0.25	0.25
EU-12 countries	0.10	0.09	0.11	0.11	0.09	0.11	0.16	0.18	0.18
EU-27 countries	0.21	0.20	0.19	0.18	0.18	0.18	0.22	0.25	0.26
World average	0.14	0.15	0.14	0.13	0.14	0.13	0.17	0.18	0.18

Source: Web of Science, searches and calculations by Fraunhofer ISI.

Furthermore, this citation rate is illustrated for six selected countries in comparison in Figure 10. There is no difference between the citation rate of English papers and all papers in the USA and Great Britain. In contrast to that, Germany's citation rates for English papers only have always be beyond the Great Britain's level, and reached a similar high level like the USA in the last two years. France, China and Brazil perform on a similar level as Germany. As we explained above, the increasingly bigger differences between citations rates with and without non-English papers in Brazil indicate the significant effect of coverage of regional journals since 2007.

Figure 10: Comparison between citation rates of English papers and all papers for selected countries in the SCIE and SSCI without self-citations



Source: Web of Science, searches and calculations by Fraunhofer ISI.

3.6 Journal-specific Scientific Regard (SR)

When the scientific performances in selected countries are inspected according to the journal-specific Scientific Regard (SR), Germany's unusually sheer drop, from 10 in 2008 to 4.6 in 2009, is presented in Table 7. The German figure plummeted to a lowest point though its SR values had always been similar to those for other leading industrialized countries like the United States in previous years. According to the SR calculation formula, the drop could be due to: comparative decrease of observed citations, comparative increase of expected citation s or a combination of the two former reasons. However, all reasons would lead to the same result, namely that German publications do not attract as many citations as expected for the journals in which they appear, i.e. the obviously diminished SR value. Table 8 showed the related figures. It could be seen that the growth rate of publications is almost two times higher than that of the observed citation, and almost two times lower than that of expected citations. So it seems reasonable to deem that the German sharp decrease in the SR value in the last year was caused by both its comparative fall of observed citations, and its comparative rise of expected citations. On the other hand, it could be found that Germany's notable increase in the SR value in 2008 was caused by the notable increase of observed citations. A follow up-study would be necessary to find out the reasons behind the different development of observed and expected citations, which even differed from that for the publications in 2009.

Table 7: Index of the journal-specific Scientific Regard (SR) for selected countries and regions in the SCIE and SSCIE without self-citations

Country/region	2001	2002	2003	2004	2005	2006	2007	2008	2009
USA	8.9	8.8	8.4	8.2	8.0	7.4	6.7	6.6	6.7
Great Britain	7.7	9.9	7.5	8.6	7.9	8.6	7.7	8.1	8.8
Germany	9.3	8.4	6.8	7.7	8.1	6.5	7.7	10.0	4.6
Japan	-5.0	-8.1	-9.1	-7.0	-8.2	-7.0	-7.4	-8.4	-10.5
France	2.9	2.5	2.2	2.3	1.8	3.1	4.3	2.8	2.5
Canada	3.2	4.9	6.7	5.5	4.8	5.9	6.2	7.7	6.4
Italy	-1.9	2.8	-3.7	-0.2	1.4	1.0	3.2	2.7	2.9
Netherlands	10.2	8.2	13.5	10.3	8.9	9.0	9.7	8.6	11.5
Switzerland	16.5	16.4	13.5	15.5	16.4	16.1	13.7	14.9	15.3
Sweden	8.8	10.6	10.4	10.9	10.4	11.1	8.3	8.4	9.6
Finland	8.1	12.5	4.0	5.3	4.5	9.8	8.6	9.8	3.9
China	-10.2	-9.3	-0.4	0.6	3.4	2.3	4.8	7.3	6.4
India	-26.9	-17.8	-16.9	-14.7	-11.5	-8.3	-9.7	-6.8	-3.7
Brazil	-26.7	-20.6	-19.2	-19.7	-12.2	-14.2	-11.6	-9.1	-9.9
Russia	-11.37	-9.33	-11.86	-3.61	-8.27	-6.55	-12.47	-5.24	-13.76
South Africa	-5.9	-13.0	-4.5	-3.2	-3.1	1.1	-3.6	5.3	4.2
EU-15 countries	2.1	2.1	1.6	1.9	2.1	2.2	2.1	2.1	1.6
EU-12 countries	-11.0	-12.7	-11.0	-7.7	-9.2	-7.0	-3.1	-9.0	-7.5
EU-27 countries	1.4	1.3	0.9	1.1	1.3	1.4	1.4	1.4	0.9
World	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Web of Science, searches and calculations by Fraunhofer ISI.

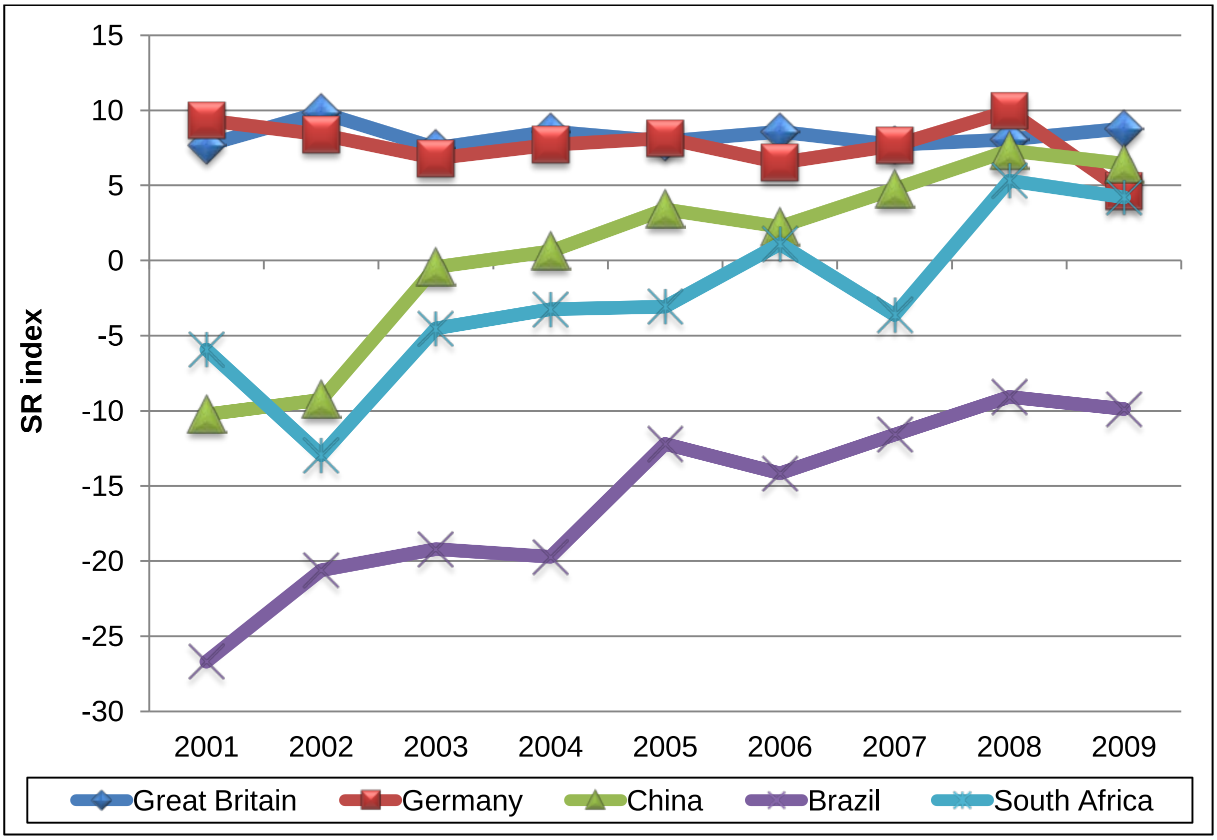
At the same time, Finland also experienced a large margin decline in the SR value. In contrast to Germany, this observation is purely based on a decline of observed citations while also the growth rate of expected citation was only half as much as world average meaning lower visibility of journals carrying Finnish publications in 2009. It is impressive that Switzerland has remained at a constantly high level within the whole observation period, with a value of about 15.

Table 8: Publication and citation in Germany and Finland in latest three years

					Growth rate	
		2007	2008	2009	2008	2009
Germany	Publication	82,537	86,236	89,951	4.48	4.31
	Observed citation	406,328	452,.187	465,161	11.29	2.87
	Expected citation	376,306.3	409,183.626	444,144.169	8.74	8.54
Finland	Publication	9,297	9,744	10,072	4.81	3.37
	Observed citation	45,254	50,984	49,566	12.66	-2.78
	Expected citation	41,523.31	46,222.23	47,666.33	11.32	3.12
World	Publication	1,116,105	1,196,264	1,248,611	7.18	4.38
	Observed citation	4,142,396	4,477,649	4,749,597	8.09	6.07
	Expected citation	4,142,396	4,477,649	4,749,597	8.09	6.07

Source: Web of Science, searches and calculations by Fraunhofer ISI.

Figure 11: Index of the journal-specific Scientific Regard (SR) for five selected countries in the SCIE and the SSCI without self-citations



Source: Web of Science, searches and calculations by Fraunhofer ISI.

On the contrary, some threshold countries including China and South Africa show rather high SR values (Figure 11), which are even better than some industrialized countries like Germany and France. However, the conclusion inferred from the result is just that China's and South Africa's publications were attracting at or above the expected citation rate for their journals, which are needed further inspection to identify their international position. As shown in Table 9, the International Alignment (IA index) for China and South Africa is much lower than world average level, with value of -20 and -18 respectively, though both countries, especially China, increased their IA figures remarkably. So the conclusion could be drawn that China's and South Africa's good performances in the SR value are due to lower impact journals which carried their papers. In consequence they also reach lower expected citations.

3.7 International Alignment (IA)

The IA-index for Germany as well as the two other non-English speaking countries France and Italy, lagging behind within European-American countries 10 years ago, have been improved up to 26 in the last year, to a similar level like Great Britain (Table 9), implying that German scientists have increasingly preferred to release their achievements to the international community in higher visible journals. Switzerland has the highest IA-index of 41 besides the highest SR figure, indicating its excellent production capacity in scientific fields. On the basis of a moderate increase of the IA value, plus a sharp decrease of the share of citations, it seems inevitable that Japan has a rather low SR value with -10.5 among the countries and regions analysed here. As new members, EU-12 countries still have a poor performance in terms of SR as well as IA indices, only being better than Brazil and Russia among the inspected countries.

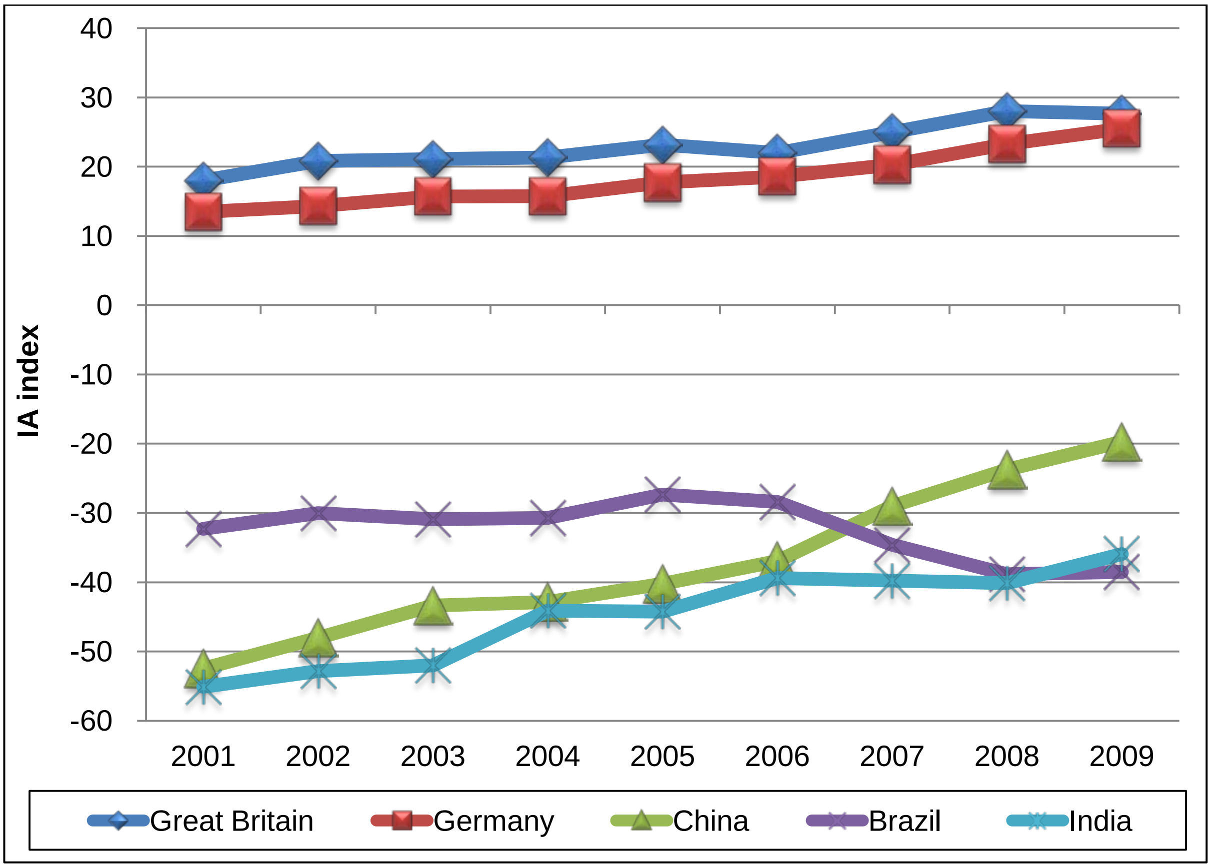
Table 9: Index of the International Alignment (IA) for selected countries and regions in the SCIE and SSCI without self-citations

Country/region	2001	2002	2003	2004	2005	2006	2007	2008	2009
USA	36	36	35	34	33	33	34	34	34
Great Britain	18	21	21	21	23	22	25	28	28
Germany	13	14	16	16	18	19	20	23	26
Japan	0	-1	-1	1	0	0	2	5	7
France	12	10	11	11	14	13	17	18	19
Canada	20	19	19	19	19	20	22	22	23
Italy	12	13	12	14	15	15	15	17	17
Netherlands	27	28	30	31	32	33	35	37	37
Switzerland	40	38	35	38	38	36	38	41	41
Sweden	21	20	22	23	23	24	27	30	30
Finland	14	17	16	16	16	14	18	23	22
China	-52	-48	-43	-43	-40	-37	-29	-24	-20
India	-55	-53	-52	-44	-44	-39	-40	-40	-36
Brazil	-32	-30	-31	-31	-27	-28	-35	-39	-39
Russia	-68	-67	-67	-63	-64	-63	-63	-63	-64
South Africa	-32	-35	-29	-24	-19	-15	-19	-16	-18
EU-15	9	10	10	10	12	12	13	15	15
EU-12	-40	-36	-35	-34	-31	-29	-33	-36	-33
EU-27	5	6	7	7	9	8	9	10	11
World	0	0	0	0	0	0	0	0	0

Source: Web of Science, searches and calculations by Fraunhofer ISI.

South Africa ranked in the first place among BRICS countries in terms of the IA index with a value of -18, which is still much below the world average. China showed an increasing trend all the time and after 2006 obvious growth of its IA figures, implying its efforts to enhance the scientific capacity and improve its international influence by rising shares of publications in higher impact journals. On the other hand, during the same period, entirely opposite results of the same extent could be found in Brazil, which already slipped down to the second-lowest one only before Russia based on the IA value. India also showed stagnant growth in IA figures since 2006 (Figure 12).

Figure 12: Index of the International Alignment (IA) for five selected countries in the SCIE and SSCI without self-citations



Source: Web of Science, searches and calculations by Fraunhofer ISI.

3.8 Disciplinary profiles – Revealed Literature Advantage (RLA)

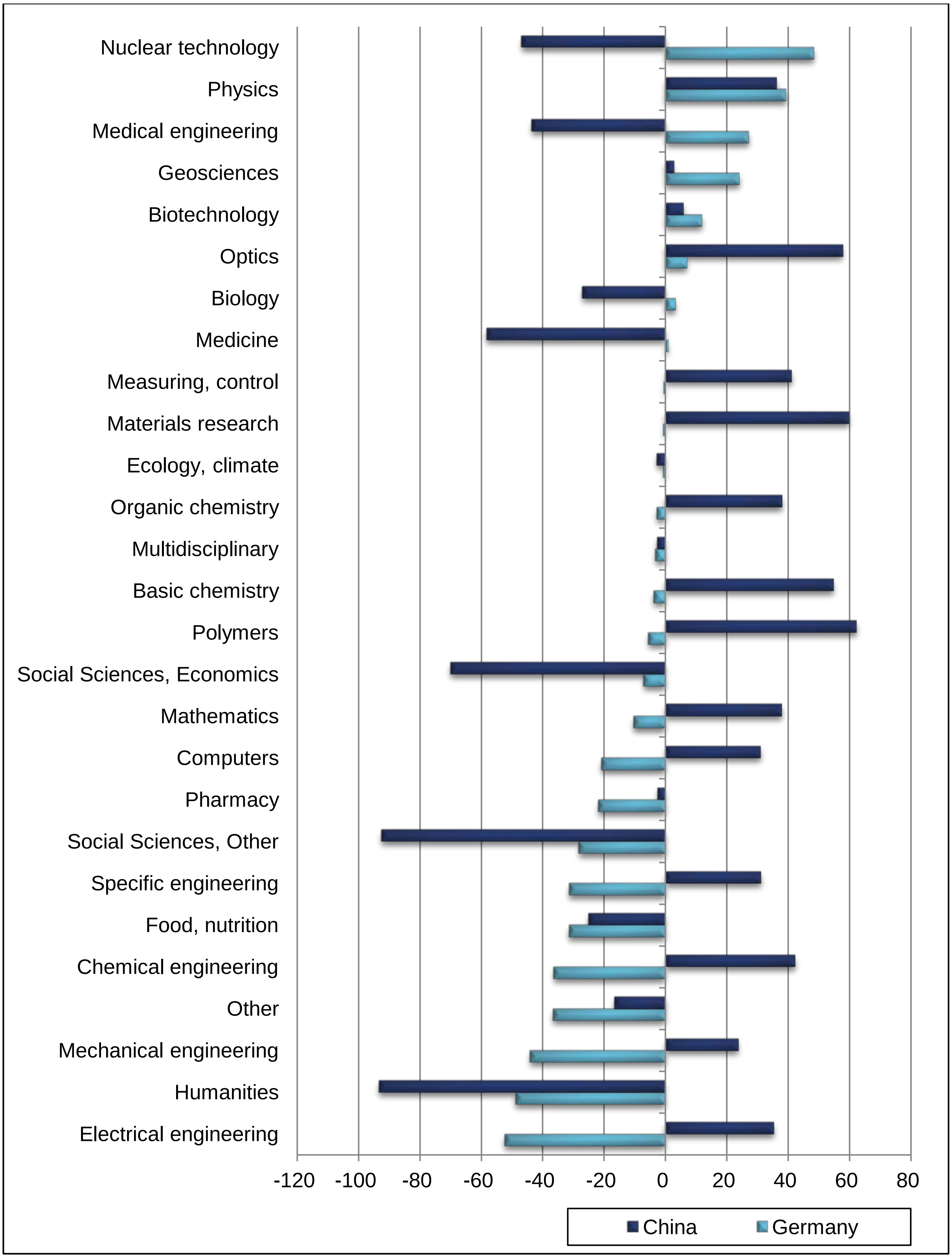
Besides the countries' aggregated data in publication and citation, their disciplinary profiles are worthy of further observation since countries have their own development priorities, which also create the bases of possible international cooperation. Profiles of Germany and China are firstly compared in Figure 13, there is little similarity in their specialization except "physics"; Germany shows high specialization values in "nuclear technology", "medical engineering", "geo-science" and "biotechnology"; while what China focuses on are "polymers", "organic chemistry", "optics", "mechanical engineering", "measuring control", "mathematics", "materials research", "electrical engineering", "computers", "chemical engineering" and "basic chemistry". There are some specializations, which are going in the totally opposite directions between the two countries like "specific engineering", "nuclear technology", "medical engineering", "mechanical engineering", "electrical engineering", "computers", “chemical engineering” and ”mathematics”. It was noted by Schmoch and others (Schmoch et al. 2012; Schmoch/Gauch 2005; Schmoch/Schulze 2010) that negative specializations of Germany in “chemical engineering” or “mechanical engineering” mostly result from the inadequate coverage of SCIE and SSCI database focusing on US-American journals. By comparison, Chinese scientists in these fields are inclined to publish their research results in US-American journals leading to high specialization values. At the same time, it is noticed that China strengthens its research on “biotechnology”, which begins to show a positive specialization index in 2011.

Both Germany and Great Britain are long-established industrialized countries with similar publication size and citation rate, but as Figure 14 shows, Great Britain has high specialization values in “humanities” and “social science” including “economics”, and environment related fields like “geo-sciences” and “ecology, climate”, as well as “medicine”, “biology” and “multidisciplinary”. It is obvious that the two countries have different emphasis on scientific activities, and Germany attaches much importance to natural science. On the other hand, inadequate coverage of German publication in social science and humanities should be taken into account.

Switzerland has always occupied the first place in terms of its observed citation rate, the SR index and the IA index based on the increasing shares of publications. It is interesting to take a close look at its superior fields in which a reputation has been built up. Figure 15 shows its strongly positive specializations including “nuclear technology”, “geo-sciences”, “medical engineering”, “multidisciplinary”, “physics”, “ecology, climate”, “biology” and “medicine”, which display a similarity to Germany except “multidisciplinary”, “ecology, climate” and “medicine”.

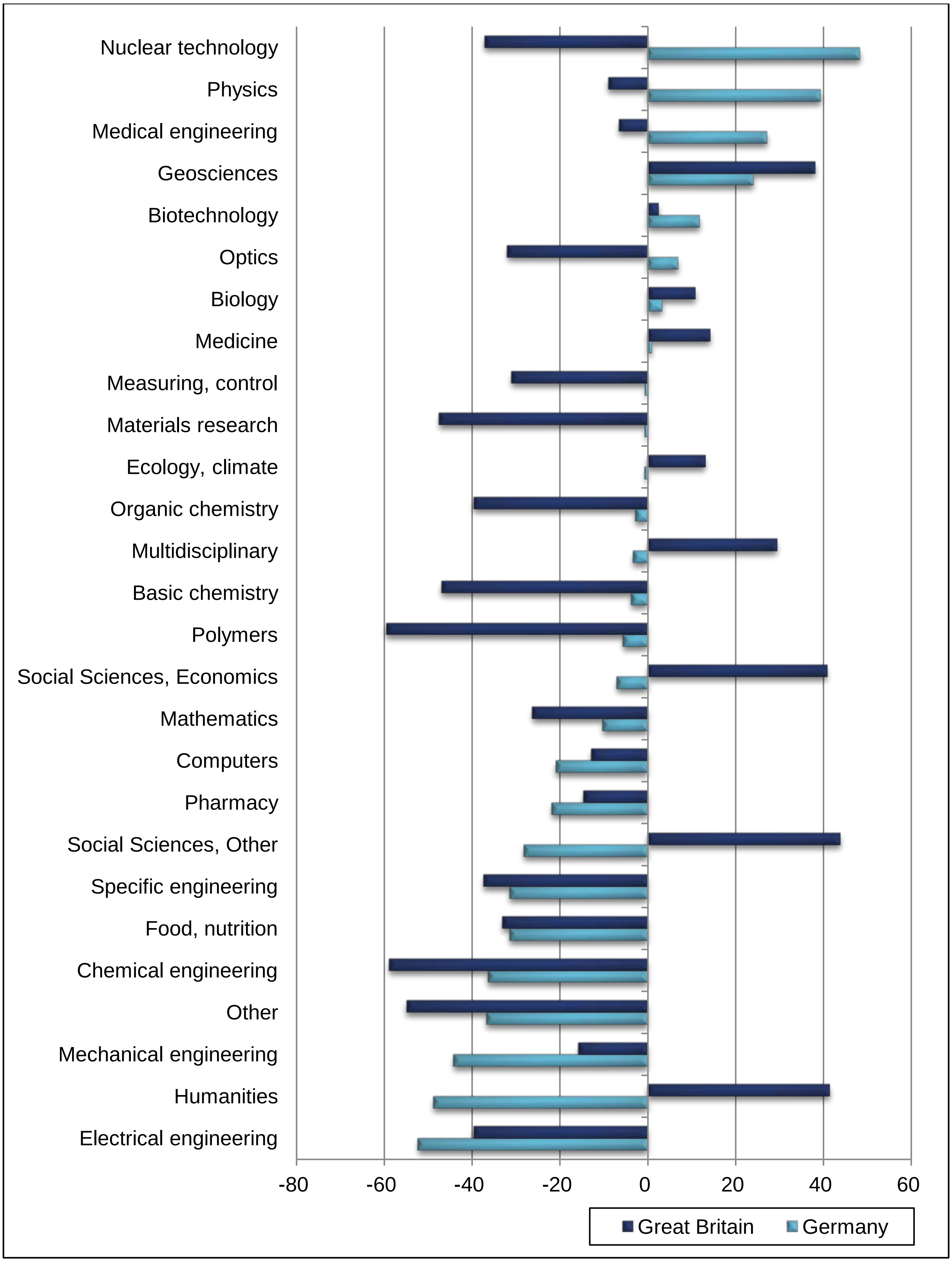
China and India publish most papers among developing countries, and both make efforts to promote their scientific impacts and the innovation competency. As to a comparison of between them (Figure 16), it shows a rather high degree of consistency in fields of specialization in respect of positive as well as negative indices despite their completely diverse development patterns, for instance in fields of “specific engineering” (+), “polymers” (+), “physics” (+), “organic chemistry” (+), “medicine” (-), “medical engineering” (-), “mechanical engineering” (+), “measuring, control” (+), “materials research” (+), “chemical engineering” (+), “basic chemistry” (+). The similar strengths could be found in both countries in the basic disciplines of life science like “organic chemistry”, “chemical engineering” and “basic chemistry”, as well as the similar weaknesses in applied disciplines such as “medicine” and “medical engineering”. However, India pays more attentions on field of “pharmacy” since it is the largest producer of generic drugs all over the world. On the other hand, the Indian scientific community concentrates on fields of “nuclear technology” and “multidisciplinary”, but not “mathematics”, “computers”, “optics” and “electrical engineering” which attract more attention of Chinese scientific community.

Figure 13: Specialization of the publications of Germany and China in 27 scientific fields in SCIE and SSCI, 2011 (RLA index)



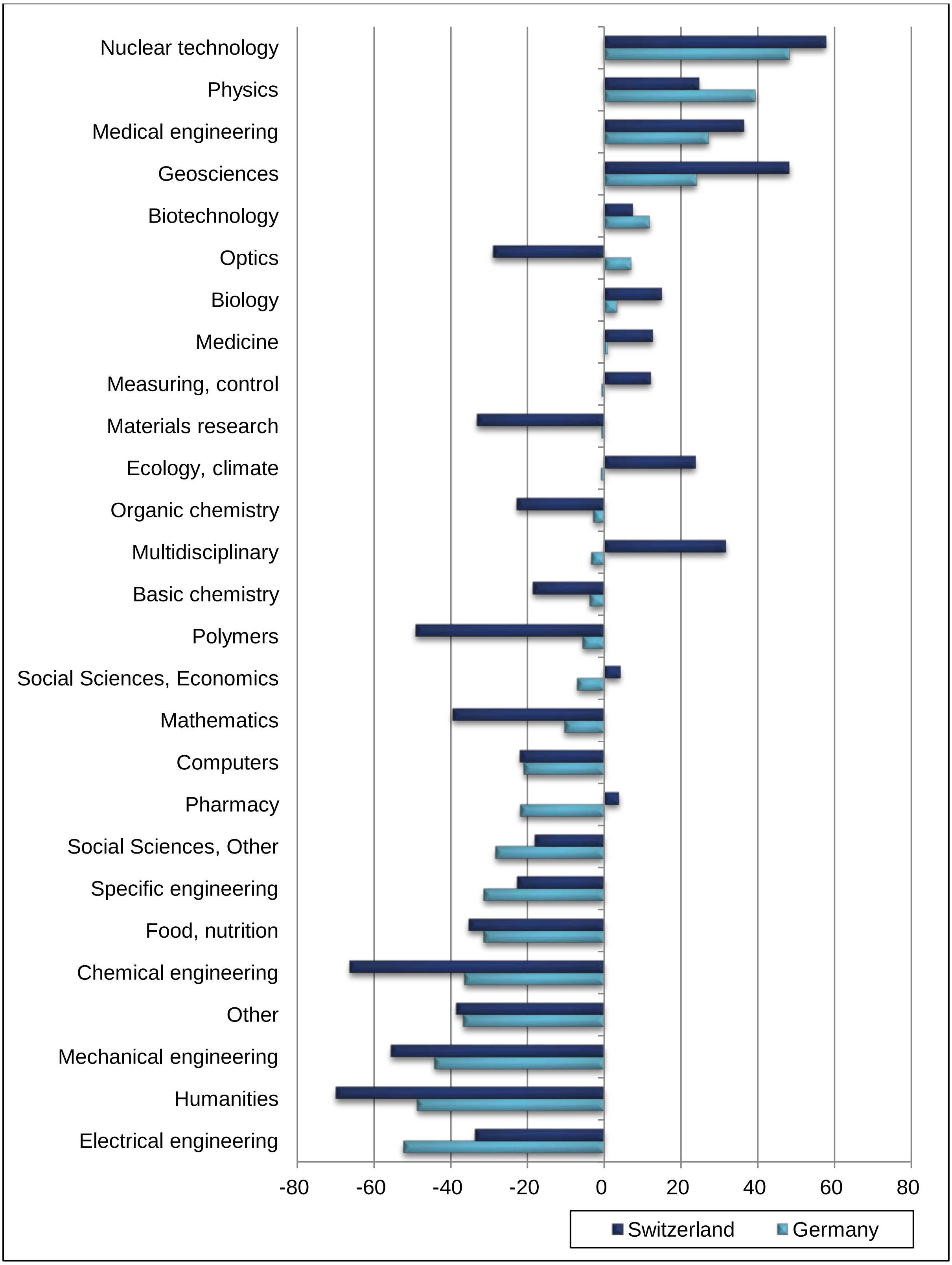
Source: Web of Science, searches and calculations by Fraunhofer ISI.

Figure 14: Specialization of the publications of Germany and Great Britain in 27 scientific fields in the SCIE and the SSCI, 2011 (RLA index)



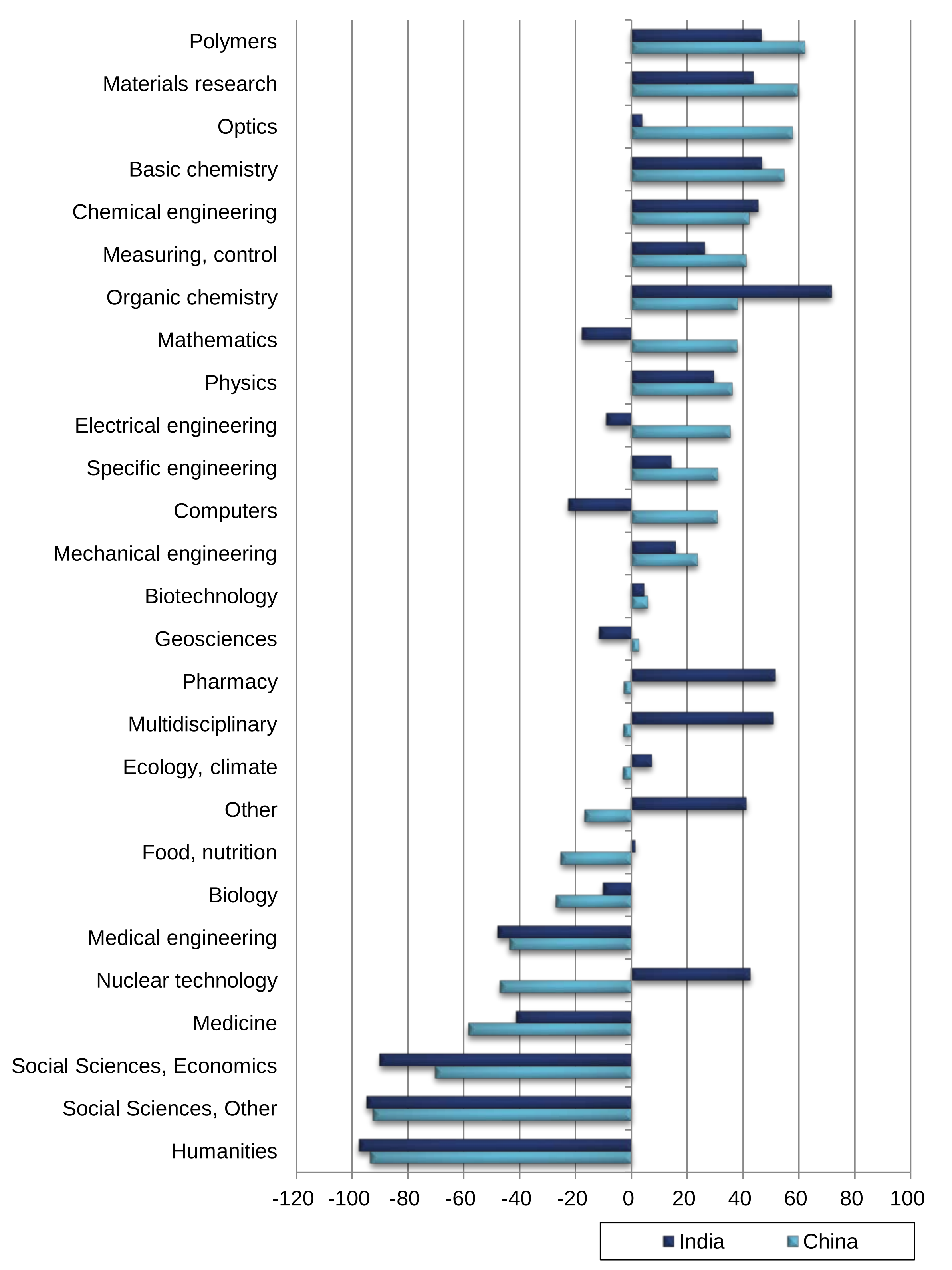
Source: Web of Science, searches and calculations by Fraunhofer ISI.

Figure 15: Specialization of the publications of Germany and Switzerland in 27 scientific fields in the SCIE and the SSCI, 2011 (RLA index)



Source: Web of Science, searches and calculations by Fraunhofer ISI.

Figure 16: Specialization of the publications of India and China in 27 scientific fields in the SCIE and the SSCI, 2011 (RLA index)



Source: Web of Science, searches and calculations by Fraunhofer ISI.

4. International co-publications

4.1 Introduction

The following part deals with international co-publications as an indicator for scientific collaborations. We analyze the overall development of Germany's (and other countries') behavior in collaborations over time. We achieve this by comparing the absolute as well as relative numbers of co-publications in different time periods, taking into account the field distribution of these co-publications and the role in a world-wide collaboration network. Presuming that there is an (at least) implicit strategy behind the collaboration patterns, we can deduce on which countries and fields Germany concentrated in the period between 2000 and 2010. Furthermore, we can observe a shift in focus for the collaborations in terms of the underlying scientific fields.

4.2 General assessment

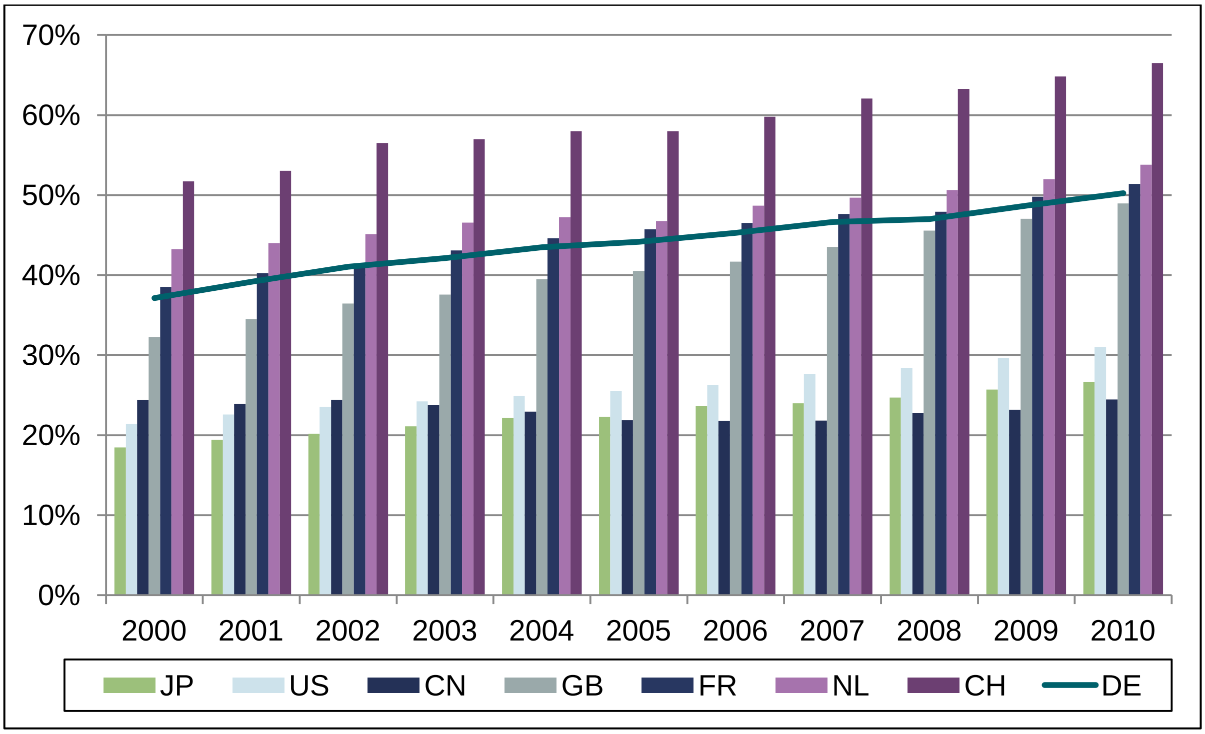
In comparison with other countries, Germany has a relatively high share in co-publications. In 2010, every second German publication was written in collaboration with a foreign author. This co-publication share is only exceeded by 6 other countries in our set.[2] The highest co-publication share can be observed for Switzerland with 66%.

Figure 17 depicts the share of co-publications for Germany in comparison to 7 other countries. The countries were chosen to present a high variety in co-publication behavior. As we will later see, these are nonetheless all countries that hold a so-called "gatekeeper" function in the world-wide collaboration network (as Germany does, too). Therefore, even though they show a high variety in terms of collaboration intensity, they all collaborate with countries that are not collaborating directly. Furthermore, they all have a similar distribution in collaboration partners. Therefore, Figure 17 shows the relative development of collaboration intensity of Germany and the other selected countries.

In this country set, only China has a stagnant share in collaboration (approx. 24%). The other countries that are below China's co-publication share in 2000, Japan and the US, exceed this value in 2010. Germany's growth in co-publication shares is similar to the other countries. For both 2007 and 2008, the co-publication share of 47% remained the same, but after 2008 a comparatively steep increase in collaboration shares can be observed.

2 Namely Switzerland, Austria, Sweden, Finland, the Netherlands and France.

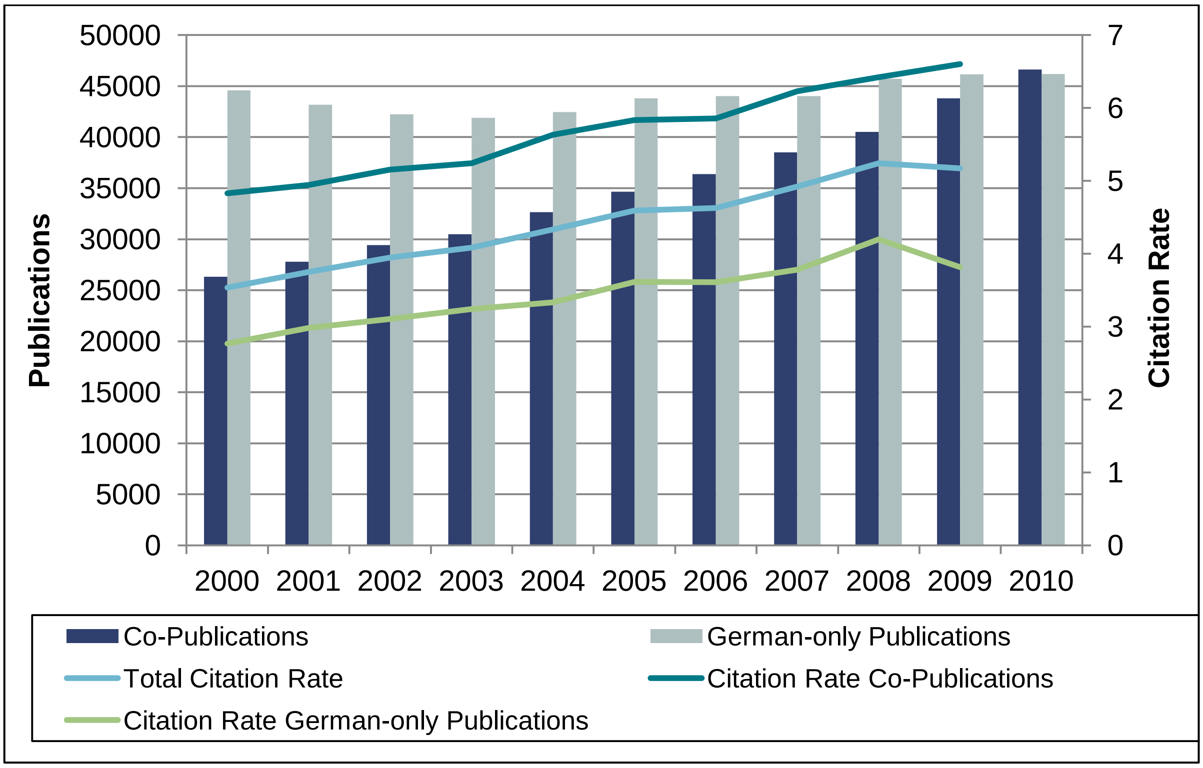
Figure 17: Comparison of co-publication share of Germany and selected countries over time



Source: Web of Science, searches and calculations by Fraunhofer ISI.

We compare the relation of publications with only German authors with those that were written in collaboration with foreign authors (Figure 18). The citation rates are only shown for the years 2000-2009 since the (citing) publications for later years are not covered sufficiently.

Figure 18: Publication number and citation rate for Germany for the years 2000-2010



Source: Web of Science, searches and calculations by Fraunhofer ISI.

The number of publications with only German authors (“German-only publications”) changes only marginally, while the number of co-publications steadily increases in this period. Thus, an observed overly increase in total publication numbers is merely a result of more co-publications.

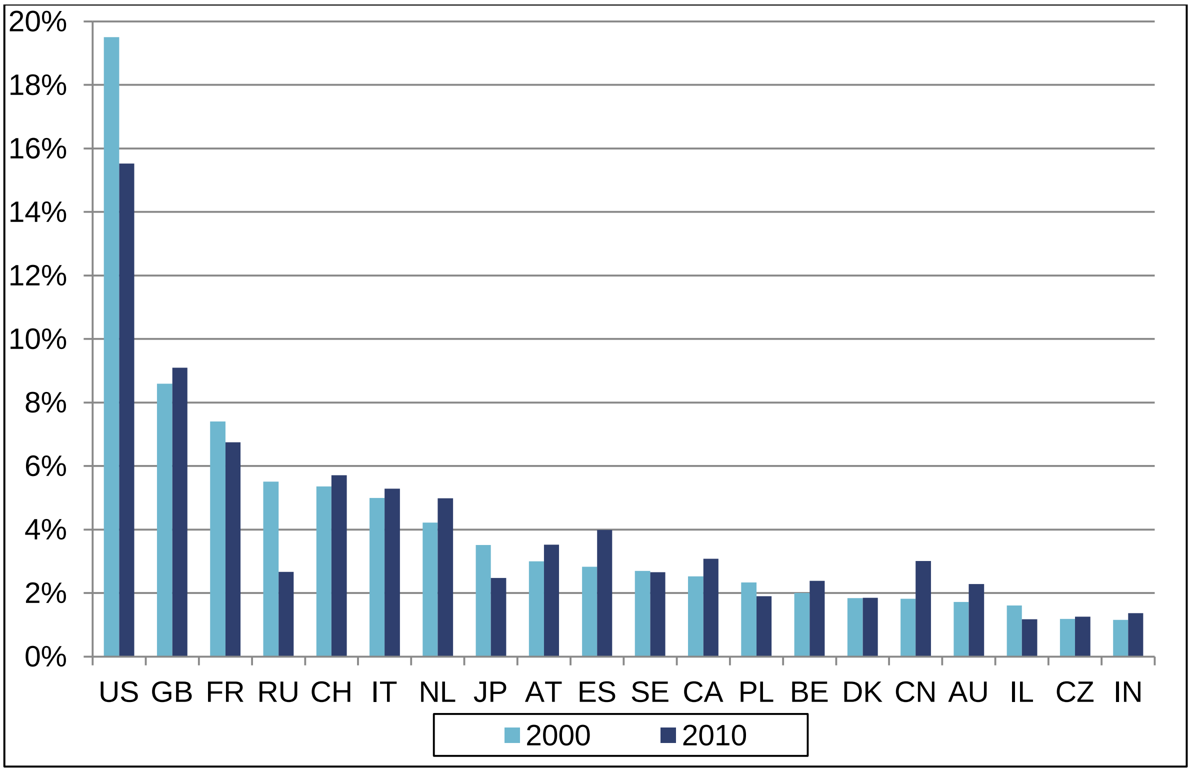
Analogously, the total citation rate depends more and more on the co-publications, as these constitute an increasing share of the German publication set. The citation rate of co-publications is in tendency higher than for non-collaborative publications, but this is a world-wide phenomenon. Nonetheless, the citation rate for German-only publications decreases in 2009 significantly. The effect is hidden by a further increase in citations for collaborative publications and an increase in their total number. In 2010 the majority of German publications were written in collaboration for the first time.

The fact that the citation rates for internationally co-authored papers tend to be higher than for national publications has already been shown in other studies (Glänzel 2001; Glänzel/Schubert 2001; Glänzel/Schubert 2004; Katz/Martin 1997; Narin et al. 1991). Moed restricted these findings to specific forms of collaboration while some citation rates might even be hurt by the collaboration with certain countries (Moed 2005). For internationally co-authored papers with at least one German author, the citation rate for 2010 also varies between 1.62 and 5.78 depending on the collaborating country. More in depth analyses would be necessary to take into account other factors that might influence this rate, e.g. the scientific field in which the co-publications are emitted. If, for instance, the collaboration with a country is mostly restricted to a field with lower average citation rates, this might be reflected in the citation rate of the co-publications as well.

Wuchty et al. (2007) showed that the probabilities for collaboration to happen as well as the chance that co-authored publications receive more citations vary among research fields. Other (qualitative) studies would therefore be necessary to decide whether the increase in co-published papers is a trend caused by changes in the German thematic focus in terms of scientific fields or really an effort to strengthen international ties.

Even-though the absolute number of co-publications increased for all collaboration partners, the relative share of co-publications with the individual countries changed in the period between 2000 and 2010 in part dramatically. Figure 19 shows the relative share of all co-publication countries in all German co-publications for the years 2000 and 2010. Despite the fact that the total number of publications with the US are still increasing (see Figure 20), the relative share of US authors in all collaborative publications is decreasing; while 19.5% of all co-publications were written with US authors in 2000, US collaborations are only notable for 15.5% in 2010.

Figure 19: Shares of countries in German co-publications (i.e. 100% correspond to all co-publications of Germany) for the years 2000 and 2010.

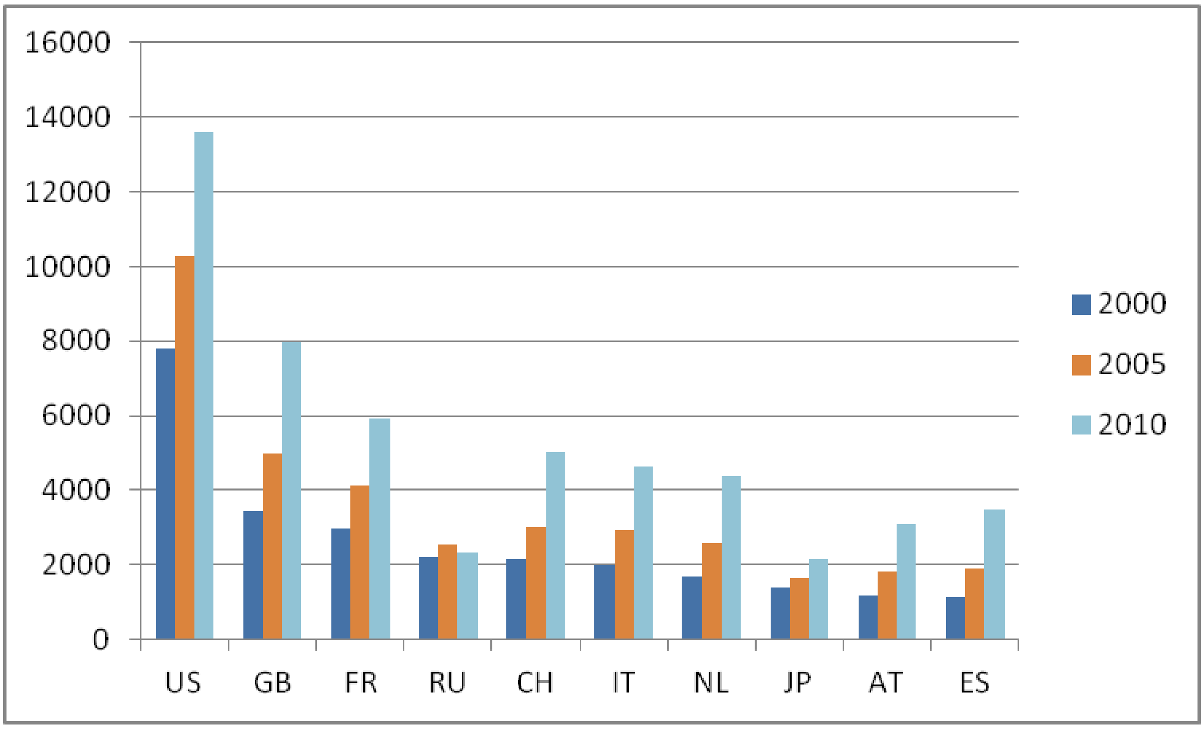


Source: Web of Science, searches and calculations by Fraunhofer ISI.

A similar observation can be made for Russia; in this case, the absolute numbers are relatively stable (see Figure 20). But since the number of overall publications and also co-publications are increasing, the share of Russia in the co-publications is decreasing. The collaboration with Russia is focussed on Physics, which is assigned as a research field to approximately 60% of all publications with Russia. The largest Russian collaboration partners in 2000 were the Russian Academy of Sciences, the Lomonosov Moscow State University and the Joint Institute for Nuclear Research with approximately[3] 891, 171 and 151 publications.

3 We can only estimate the number of publications with specific organizations since organization names are not standardized in the WoS. Thus, the numbers provided above are estimates of the lower bound of publications that are connected with the specific organizations.

Figure 20: Top 10 collaboration partners of Germany for the years 2000 and their development in the years 2005 and 2010



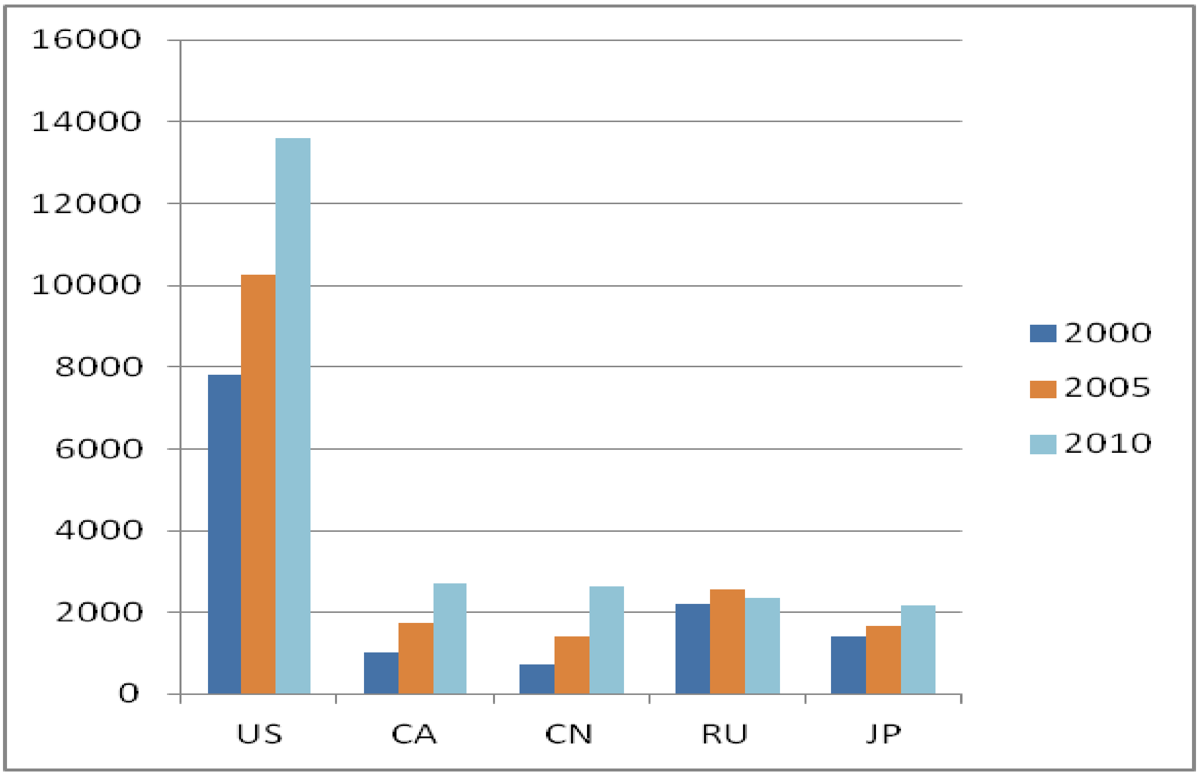
Source: Web of Science, searches and calculations by Fraunhofer ISI.

What proves to be even more interesting is a closer look at the German-Russian co-publications. The top-cited ones are publications that were written with a multitude of authors from various countries. For instance, the article "Global Positioning System constraints on plate kinematics and dynamics in the eastern Mediterranean and Caucasus", which was published in 2000, was written by 28 authors from 12 countries. Interesting would be a further study that would analyze whether similar observations can be made in the overall dataset and for other countries, i.e. whether collaborations with specific countries only arise in large consortiums.

Coming back to the overall statistics of Germany, collaborations with Great Britain, other EU countries and especially China increased. All in all, the collaborations seem to become more unified for all countries and thus more diverse.

The already mentioned Figure 20 shows the absolute numbers of publications with the top 10 collaboration partners of Germany. The countries on the x-axis are ordered according to the number of publications in 2000. The stable number of collaborations with Russia leads to a ranking of this country on rank 11 in 2010 instead of 4. Similarly, the small increase in publications with Japan leads to rank 13 in 2010. In their stead, Canada and China would be included in the list of top 10 collaboration partners in 2010. Figure 21 depicts the development of the absolute co-publication numbers of the affected countries in comparison with the USA. In combination with Figure 19 it becomes clear that the small changes in absolute co-publication numbers for Russia and Japan even lead to a decrease in co-publication shares. Even though the collaboration intensity with Canada and China are on a similar level in 2010, the increase in publications with China is tremendous: The absolute number increased by the factor 3.6 in the period of 2000 to 2010. Still, due to the overall increase in co-publications, the relative share of these publications only increased from 1.8% to 3.0%.

Figure 21: Development of the number of German publications with the USA, Canada, China, Russia and Japan in the years 2000, 2005 and 2010

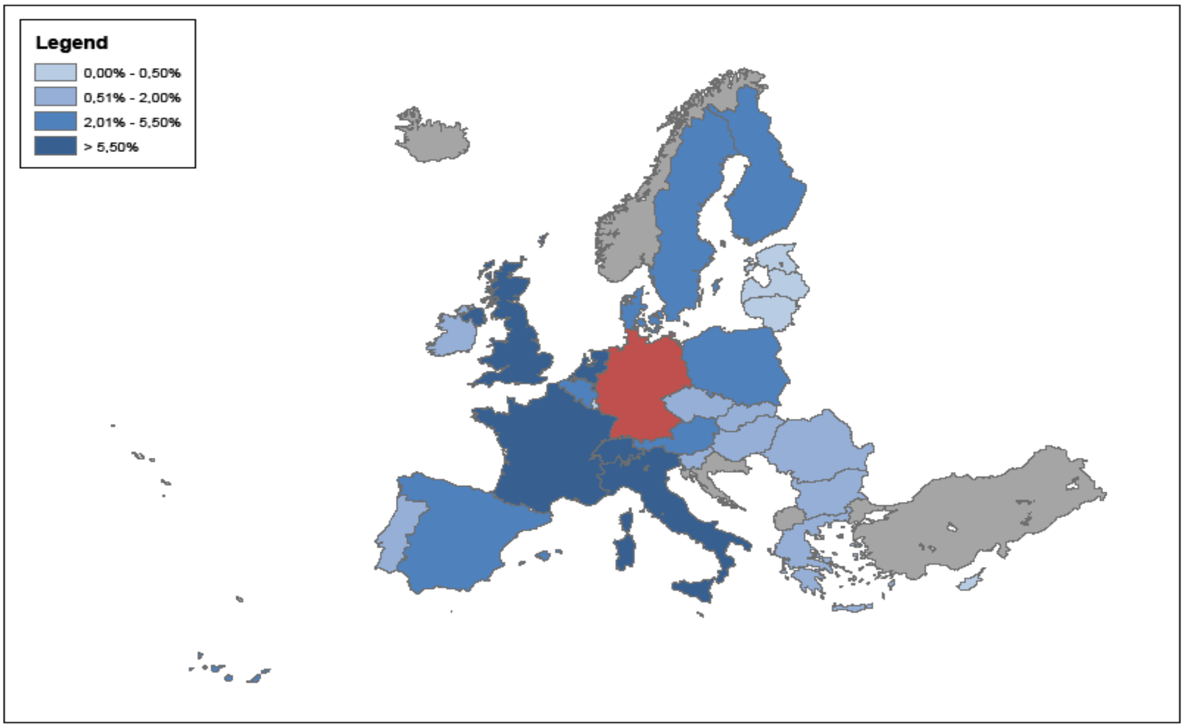


Source: Web of Science, searches and calculations by Fraunhofer ISI.

A look on the maps for the years 2000 and 2010 show that there are more or less minor changes in the course of time (Figure 22 and Figure 23). The coloring of the countries corresponds to the percentage of publications that were written with the respective country. Therefore, in contrast to Figure 19, the percentage is calculated on the basis of all German publications, not only the co-publications.

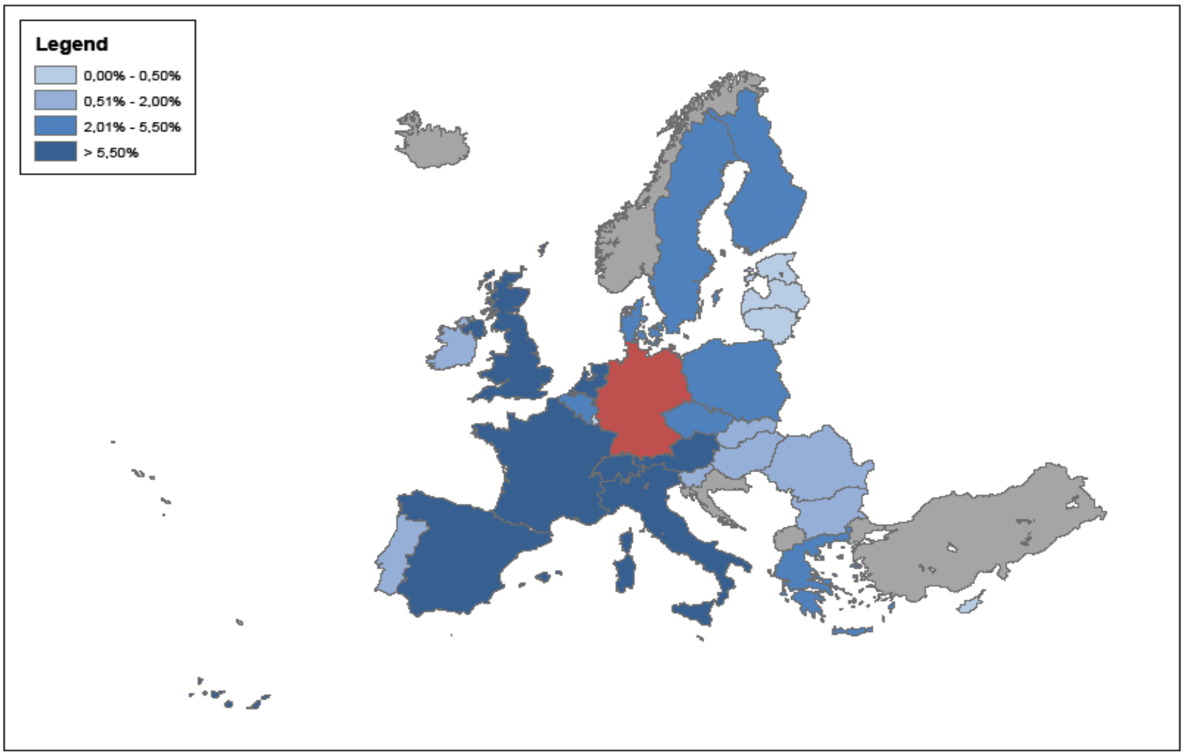
Noteworthy, mostly changes for the better can be observed. The number of German publications with Finland decreases between 2000 and 2004, but increases thereafter again to a higher level. More publications with the Czech Republic were emitted in this time period and stayed on a similar level over time. From Figure 19 we can derive that in comparison to all co-publications, this was a minor change. Furthermore, the collaboration with Austria and Spain intensified after 2004, so that the final graph depicts an acute and well-distributed collaboration within the EU. This trend has already been corroborated in another study by Hoekman et al., in which the authors concluded “that Europe is to some extent breaking down geographical barriers and is moving away from localised ‘gravity holes’” (Hoekman et al. 2010).

Figure 22: Map of EU collaboration partners of Germany, 2000.



Source: Web of Science, searches and calculations by Fraunhofer ISI.

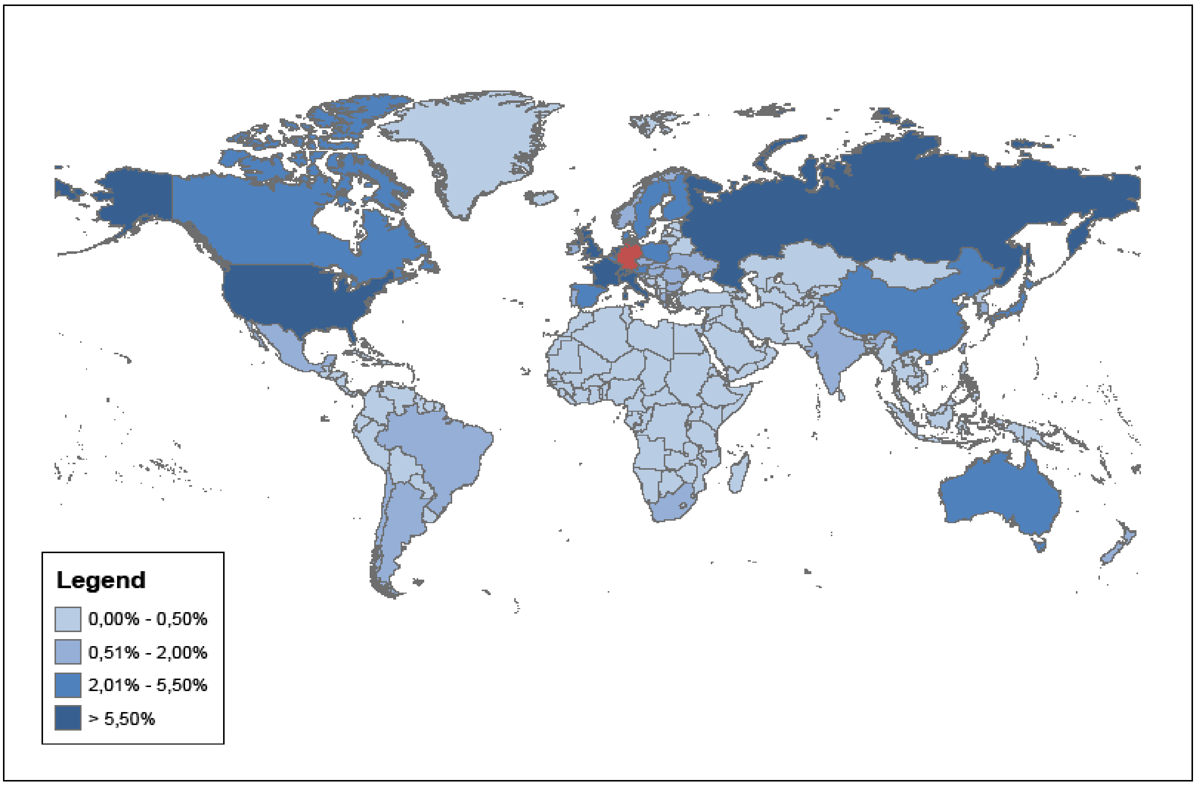
Figure 23: Map of EU collaboration partners of Germany, 2010.



Source: Web of Science, searches and calculations by Fraunhofer ISI.

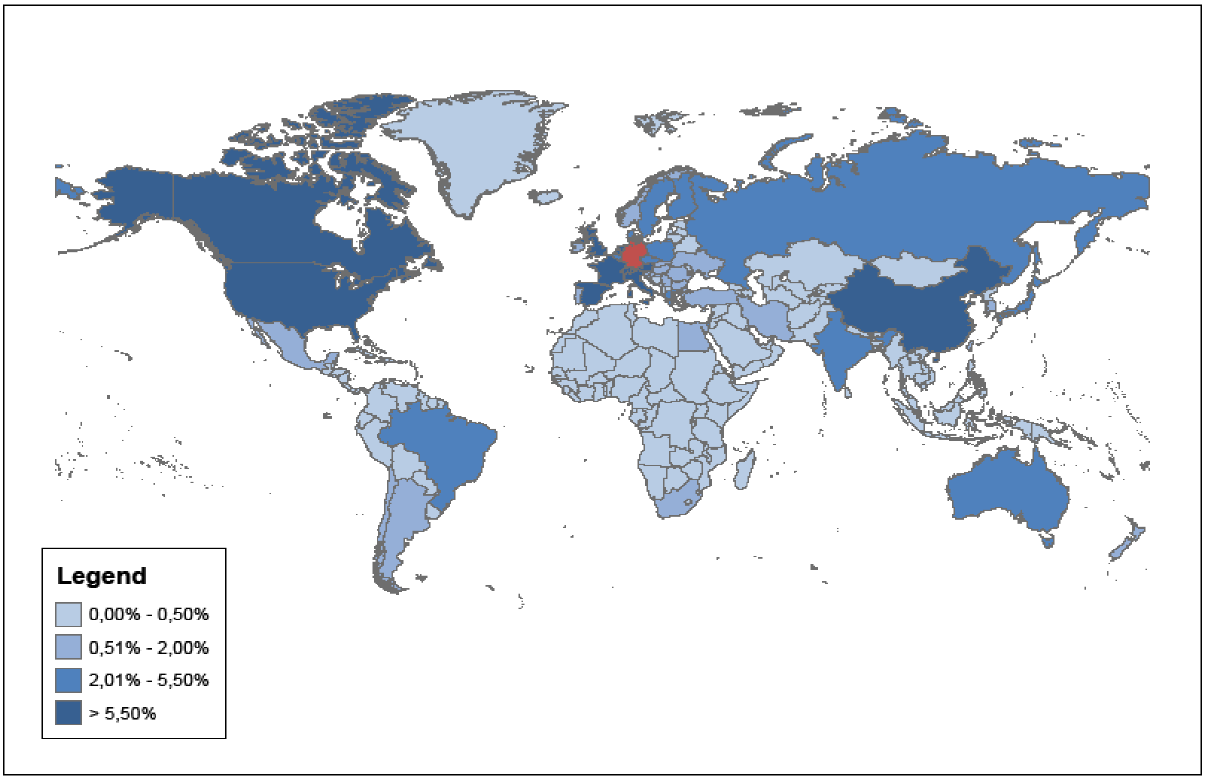
In a worldwide view, further changes in collaboration are notable (Figure 24 and Figure 25). Foremost, the collaboration with the BRICS countries changed notably. As already explained in connection with the EU and the overall view in Figure 19, the relative share of collaborations with Russia is decreasing. On the other hand, the share of co-publications with China doubled. Next to the USA and Canada, China meanwhile belongs to the most important German partners outside Europe. The collaboration with India and Brazil intensified by 0.8% and 0.5% respectively, i.e. of all publications emitted by Germany in 2010 2.58% and 2.13% respectively were written in collaborations with India or Brazil. This changed the classification of these countries according to the proposed intensity classes. The only other country for which a noteworthy change could be measured is Canada, with an increase of 1.9%. These findings corroborate the results in a study by Waltman et al. (2011); the collaboration intensity has increased even with countries that have the farthest distance to Germany, Thus, the geographical distance seems to hinder the collaboration less intensely.

Figure 24: Map of worldwide collaboration partners of Germany, 2000



Source: Web of Science, searches and calculations by Fraunhofer ISI.

Figure 25: Map of worldwide collaboration partners of Germany, 2010



Source: Web of Science, searches and calculations by Fraunhofer ISI.

4.3 Field-specific co-publications

To assess the motivation to co-author publications, we analyzed the scientific fields in which the papers were published. Table 10 shows the three major fields for a selection of countries of German collaborators. Most co-authored articles are classified in multidisciplinary fields, “Food and Nutrition”, Chemistry, Pharmacy, Computers, “Ecology and Climate” and the field “Other”, which covers mostly Forestry and Agricultural Sciences but also everything else that does not fit into one of the major fields. We know from the RLA analysis, that these are the fields in which Germany is not specialized in, i.e. the focus of German research covers other topics (see section 2.6). Thus, collaborations with other countries in these fields could be a mean to access expertise or data generated in other countries. Vice versa, the remaining fields in Table 10 could be fields in which foreign authors seek expertise in Germany, e.g. in Biology or Optics. Alternatively, collaborations in less-specialized fields could also show that in these cases the share of knowledge poses no threat to Germany’s hegemony.

Table 10: Fields in which the co-publications with the top 10 collaboration countries were published

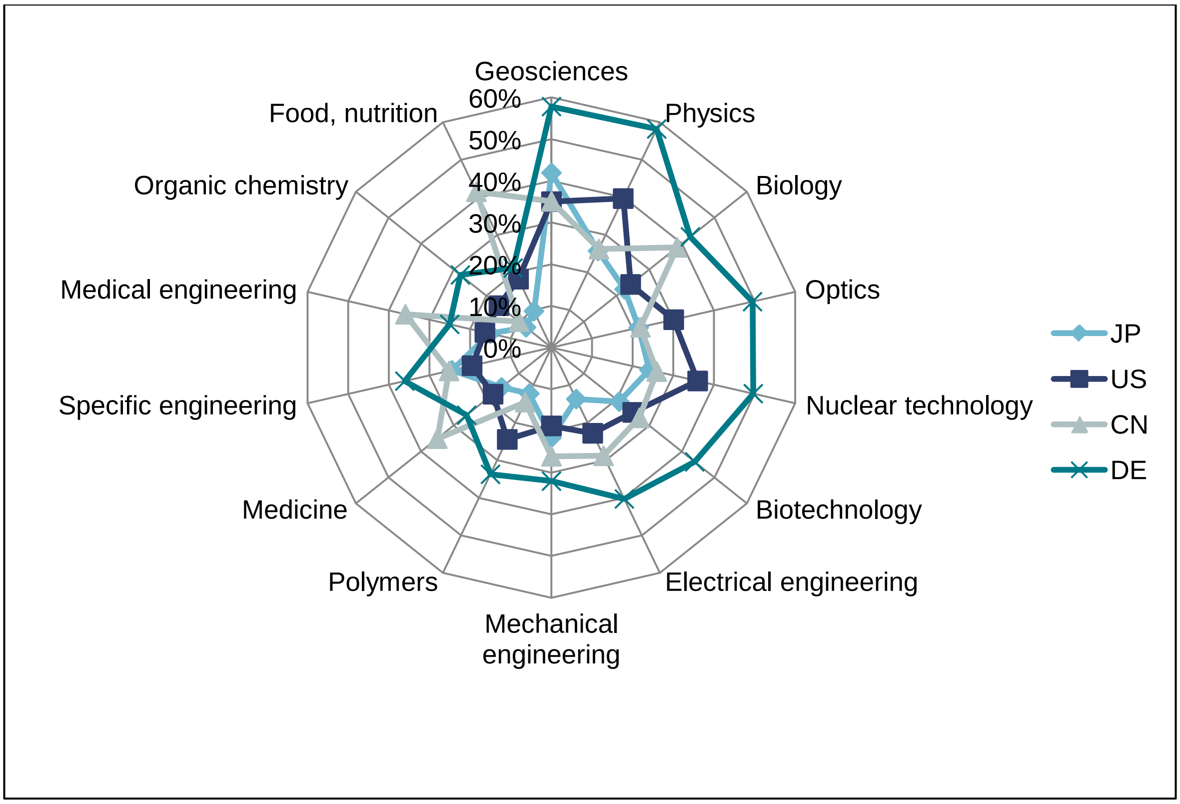
Country	Field 1	Field 2	Field 3
US	Multidisciplinary	Chemical engineering	Computers
GB	Other	Biology	Ecology, climate
FR	Other	Biology	Ecology, climate
CH	Polymers	Optics	Materials research
IT	Optics	Basic chemistry	Organic chemistry
NL	Food, nutrition	Pharmacy	Specific engineering
RU	Physics	Other	Mechanical engineering
ES	Food, nutrition	Chemical engineering	Polymers
AT	Optics	Organic chemistry	Mechanical engineering
CA	Multidisciplinary	Medical engineering	Food, nutrition

Source: Web of Science, searches and calculations by Fraunhofer ISI.

When analyzing these fields in comparison with the RLA Index on Germany's specialization, we can distinguish between Germany's relative weaknesses / less pronounced and major fields (see section 2.6). The term "non-specialized" in this context means fields that play a minor role in the German profile compared to its role in the worldwide profile, i.e. they have an RLA Index of below 0. Analogously, fields with a high RLA Index are the fields in which Germany is specialized. For the non-specialized fields, a high overlap with the top fields of the collaboration partners can be observed (see Table 10).

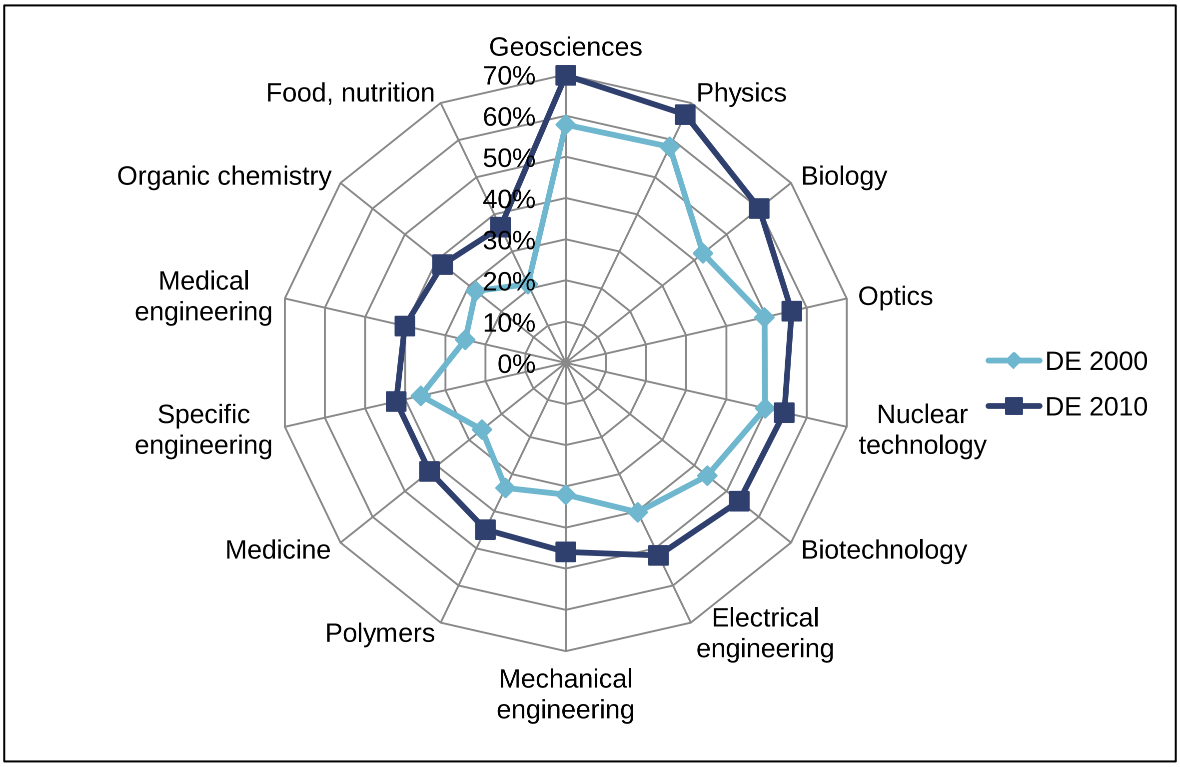
In contrast to that, the shares of collaborations are rather high in the strong German fields like Nuclear Technology, Physics and Geosciences in 2000, i.e. in the beginning of our analyzed time period (see Figure 26). Therefore, we can assume that Germany shares its expertise in these fields with other countries. All in all, when compared to Japan, China and the US, Germany shows relatively high collaboration in all fields. Only in Medicine, Medical Engineering and Food and Nutrition are the German co-publication values smaller than those for China.

Figure 26: Field profiles according to share of co-publications for Japan, the USA, China and Germany in the year 2000



Source: Web of Science, searches and calculations by Fraunhofer ISI.

Figure 27: Field profiles according to share of co-publications for Germany in the years 2000 and 2010



Source: Web of Science, searches and calculations by Fraunhofer ISI.

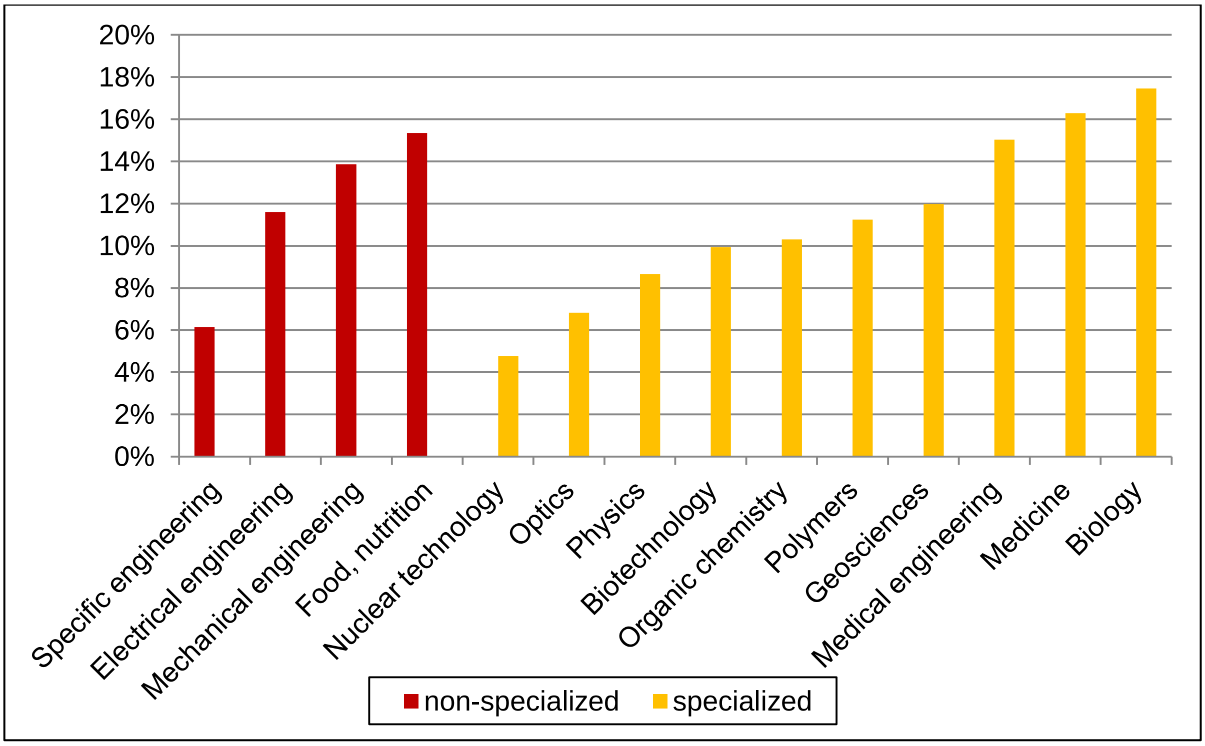
Figure 27 shows the collaboration shares for Germany for the years 2000 and 2010 in comparison. German collaboration in the fields Physics, Geosciences and Biology was growing until 2010 despite its already high collaboration level. Furthermore, Germany only reaches highest levels – compared to the other three countries – in its major fields of specialization. Between the years 2000 and 2010 (Figure 27), the share of co-authored papers was increased in these major fields, namely Biology, Medicine and Medical Engineering.

We can derive an overall trend more clearly when comparing the increase in collaborations in 2000 and 2010 for Germany's outstanding as well as non-specialized fields (see above).

Figure 28 shows the increase in shares for the different fields in the period between 2000 and 2010. The above named fields Biology, Medicine and Medical Engineering were increasing in major parts as well as the neglected fields "Food, nutrition" and Mechanical Engineering. The share of co-publications in the field "Nuclear Technology" did not increase in equal terms as in other main fields. Despite political changes in the last years this still is one of Germany's major fields. But the changes in the research focus become visible in the comparatively small increase in co-publications in this field as well. The main collaboration partners for this field in 2010 are the US, Russia and France.

With the exception of specific engineering, the increase in collaboration in the non-specialized fields mirrors the development in the other fields. In Food and nutrition, the main collaboration partner, the USA, is no longer present in even the three major co-publishing countries. These are now Great Britain, the Netherlands and France.

Figure 28: Increase in co-publication share for Germany in its non-specialized and specialized fields in 2010 in comparison with 2000



Source: Web of Science, searches and calculations by Fraunhofer ISI.

4.4 Social Network Analysis

A social network analysis (SNA) of the EFI countries in the years 2000 and 2010 shows the different roles that the countries play in an international context (Figure 29).

The edges vary in their thickness according to the degree of collaboration between two countries. In this network, we use the absolute values to represent the overall intensity of collaboration. Thus, all analyses might be prone to size effects. But the goal of the network analysis is to identify the key players in a network, so this is even a desired effect.

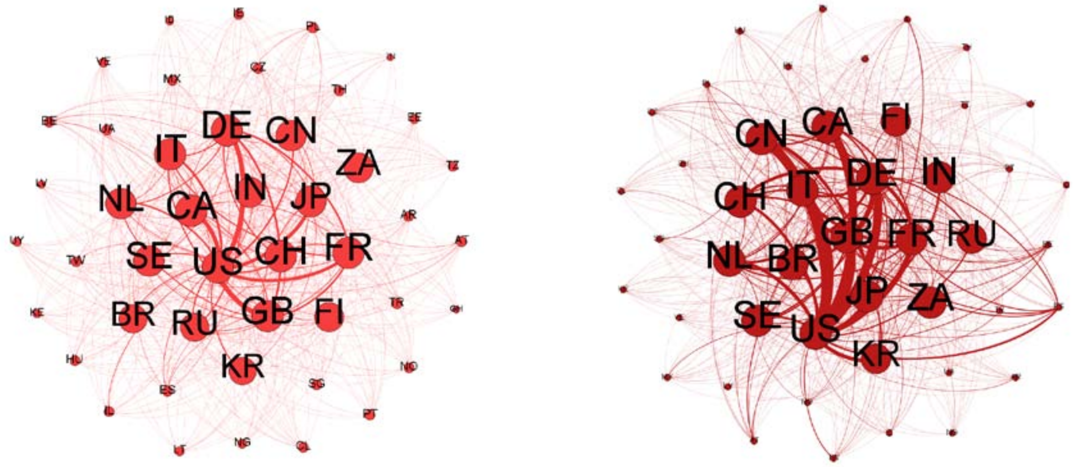
The color represents the betweenness centrality of the country, where a darker color indicates a higher betweenness centrality. The betweenness centrality of a country X in this context stands for the number of countries Z and Y, that do not collaborate but are connected indirectly via country X. We call the countries that connect extensively other yet unconnected countries “gate keepers”, since this countries keep the knowledge flow in the whole network going. Thus, with the help of gate keepers, scientific knowledge might have “sources” and “sinks” in the words of network analysis, but the knowledge is wider distributed in the overall system. In the extreme case of a network without any gatekeepers or any indirect connections, there would be only bidirectional connections between countries. This shows the mere importance of gate keepers in any knowledge distribution system.

All gate keepers in 2000 are represented in 2010 as well, so no major changes are observable in the collaboration landscape. Germany was and still is one of the countries, which are involved in most of the co-publications. By this, Germany is also able to connect other countries that do not collaborate directly. In the graph, Germany’s strong ties with the US, France, Suisse and Italy become visible. In comparison with 2010, we can see that all connections were strengthened.

In the absolute values for the betweenness centrality, slight changes can be observed that have no effect on the overall structure. The US reduce their betweenness centrality value from 0.029 to 0.025. Bearing in mind that these values are in general very low, it becomes obvious that the gate keeper functions are more equally shared in 2010 than in 2000. In 2010, the values among the gate keepers vary between 0.023 and 0.025, whereas in 2000 there was a difference of 0.01 between the leading gate keeper nations like the US and Germany and less concise countries, e.g. South Korea and Brazil.

The country on the lower right with the new thicker edges in 2010 is Spain, so we can deduce that Spain has increased its collaboration effort. The same holds for Belgium, which is depicted right next to Spain. Both countries still do not serve as gatekeepers, i.e. they do not establish new connections between yet not connected countries. Therefore, they do not add to the knowledge transfer in the overall system, but improve only their direct knowledge flows.

Figure 29: Social Network Analysis for the EFI countries in the years 2000 and 2010

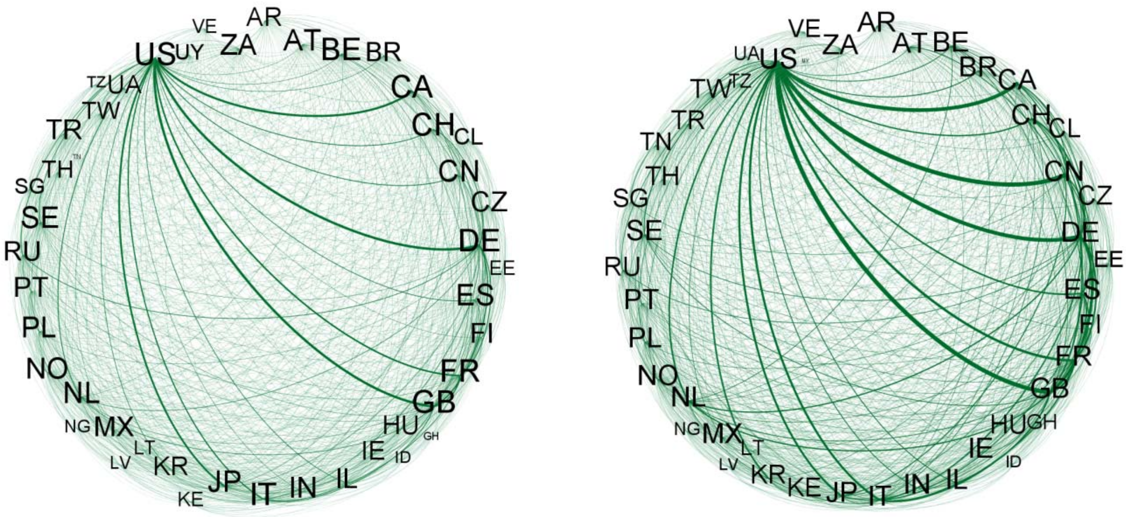


2000 *2010*

Source: Web of Science, searches and calculations by Fraunhofer ISI.

Figure 30 shows the SNA for all countries in the years 2000-2010. Again, the thickness of the edges represents the degree of collaboration between any two countries. The size of the country abbreviation shows the total number of collaborations with different countries, i.e. the font size is large when a country has co-publications with several different countries and vice versa. All countries are arranged in a circle for better visibility.

Figure 30: Social Network Analysis for all countries in the years 2000, 2004, 2008 and 2010



2000 **2010**

Source: Web of Science, searches and calculations by Fraunhofer ISI.

Also, the countries were clustered according to this collaboration pattern, i.e. based on their connections with other countries. Thus, countries with the same color have a similar pattern in collaborations; they have the same partners and the same proportion of publications with these partners. Since all countries are colored the same in this SNA, we can deduce that despite the general intensification of collaboration effort, the overall distribution among publication partners stayed the same. This is even true for countries that specifically increased their absolute number of co-publications, e.g. Spain.

The high connectivity of the US with most of the other countries is even more present in these graphs. Few overall changes can be observed except an overall trend for collaboration intensification. As was already explained before, the goal of this SNA was to detect the key players in the network and this metric is prone to size effects. But the importance of a country as a gate keeper or collaboration partner should precisely correlate with its overall importance in scientific communication.

References

Achleitner, A.-K./Allmendinger, J./Grupp, H./Harhoff, D./Luther, J./Soete, L./Schmoch, U./Stenke, G. (2008): Research, Innovation and Technological Performance in Germany. EFI Report 2008. Berlin: Expertenkommission Forschung und Innovation (EFI).

Adams, J. (2005): Early citation counts correlate with accumulated impact, Scientometrics, 63, 567-581.

Bavelas, A. (1948): A mathematical model for group structure, Human Organizations, 7, 16-30.

Blondel, V.D./Guillaume, J.L./Lambiotte, R./Lefebvre, E. (2008): Fast unfolding of communities in large networks, Journal of Statistical Mechanics: Theory and Experiment, 2008.

BMBF (2008): Deutschlands Rolle in der globalen Wissensgesellschaft stärken. Die Strategie der Bundesregierung zur Internationalisierung von Wissenschaft und Forschung. Berlin: BMBF.

Brandes, U. (2001): A faster algorithm for betweenness centrality, Journal of Mathematical Sociology, 25, 163-177.

Costas, R./Leeuwen, T.N./Bordons, M. (2010): Self-citations at the meso and individual levels: effects of different calculation methods, Scientometrics, 82, 517-537.

Fortunato, S./Castellano, C. (2009): Community structure in graphs. In: Meyers, R.A. (Hrsg.): Encyclopedia of Complexity and Systems Science, Vol.1. Berlin, Germany: Springer, eprint arXiv:0712.2716.

Freeman, L.C. (1977): A set of measures of centrality based on betweenness, Sociometry, 40, 35-41.

Freeman, L.C. (1979): Centrality in social networks: Conceptual clarication, Social Networks, 1, 215-239.

Gauffriau, M./Larsen, P.O./Maye, I./Roulin-Perriard, A./Ins, M. (2008): Comparisons of results of publication counting using different methods, Scientometrics, 77, 147-176.

Glänzel, W. (2001): National characteristics in international scientific co-authorship relations, Scientometrics, 51, 69-115.

Glänzel, W./Schubert, A. (2001): Double effort = double impact? A critical view at international co-authorship in chemistry, Scientometrics, 54, 199-214.

Glänzel, W./Schubert, A. (2004): Analysing Scientific Networks Through Co-Authorship. In: Moed, E.H./Glänzel, W./Schmoch, U. (Hrsg.): Handbook of quantitative science and technology research. The use of publication and patent statistics in studies of S&T systems. Dordrecht: Kluwer Academic Publishers, 257-276.

Glänzel, W./Thijs, B./Schlemmer, B. (2004): A bibliometric approach to the role of author self-citations in scientific communication, Scientometrics, 59, 63-77.

Grupp, H./Schmoch, U./Hinze, S. (2001): International alignment and scientific regard as macro-indicators for international comparisons of publications, Scientometrics, 51, 359-380.

Hoekman, J./Frenken, K./Tijssen, R.J.W. (2010): Research collaboration at a distance: Changing spatial patterns of scientific collaboration within Europe, Research Policy, 39, 662-673.

Katz, J.S./Martin, B.R. (1997): What is research collaboration?, Research Policy, 26, 1-18.

Larsen, P.O./von Ins, M. (2010): The rate of growth in scientific publication and the decline in coverage provided by science citation index, Scientometrics, 84, 575-603.

Michels, C./Schmoch, U. (2011): Growth of Science and Database Coverage (Full paper), Proceedings of the 13th Conference of the International Society for Scientometrics and Informetrics (ISSI), 4.-7. Juli 2011. Durban (ZA).

Moed, H. (2005): Citation Analysis in Research Evaluation. Dordrecht: Springer.

Narin, F./Stevens, K./Whitlow, E. (1991): Scientific co-operation in Europe and the citation of multinationally authored papers, Scientometrics, 21, 313-323.

Nederhof AJ (2006): Bibliometric monitoring of research performance in the social sciences and the humanities: A review, Scientometrics, 66, 81-100.

Newman, M.E.J. (2004): Analysis of weighted networks, Physical Review E - Statistical, Nonlinear, and Soft Matter Physics, 70, 056131.

Newman, M.E.J. (2006): Modularity and community structure in networks, Proceedings of the National Academy of Sciences of the United States of America, 103, 8577-8582.

Newman, M.E.J./Girvan, M. (2004): Finding and evaluating community structure in networks, Physical Review E - Statistical, Nonlinear, and Soft Matter Physics, 69, 026113.

Sabidussi, G. (1966): The centrality index of a graph, Psychometrika, 31, 581-603.

Schmoch, U./Qu, W. (2009): Performance and Structures oft he German Science System in an International Comparison 2008 (= Studien zum deutschen Innovationssystem Nr. 6-2009). Berlin: Expertenkommission für Forschung und Innovation (EFI).

Schmoch, U./Gauch, S. (2005): Leistungsfähigkeit und Strukturen der Wissenschaft im internationalen Vergleich 2004 (= Studien zum deutschen Innovationssystem Nr. 6-2005). Berlin: Bundesministerium für Bildung und Forschung (BMBF).

Schmoch, U./Michels, C./Schulze, N./Neuhäusler, P. (2012): Performance and Structures of the German Science System 2011, Germany in an international comparison, China's profile, behaviour of German authors, comparison of the Web of Science and SCOPUS (= Studien zum deutschen Innovationssystem Nr. 9-2012). Berlin: Expertenkommission Forschung und Innovation EFI.

Schmoch, U./Schulze, N. (2010): Performance and Structures of the German Science System in an International Comparison 2009 with a Special Feature on East Germany (= Studien zum deutschen Innovationssystem Nr. 9-2010), Expertenkommission Forschung und Innovation (EFI) (Hrsg.). Berlin.

Testa, J. (2012): The Thomson Reuters Journal Selection Process, http://thomsonreuters.com/products_services/science/free/essays/journal_selection_process/ .

Van Raan, A.F.J./Van Leeuwen, T.N./Visser, M.S. (2011): Severe language effect in university rankings: particularly Germany and France are wronged in citation-based rankings, Scientometrics, 88, 495-498.

Van Raan, A.J.F. (2004): Measuring Science. Capita Selecta of Current Main Issues. In: Glänzel, W./Moed, H./Schmoch, U. (Hrsg.): Handbook of Quantitative Science and Technology Research. The Use of Publication and Patent Statistics in Studies on R&D Systems. Dordrecht; Norwell; New York; London: Kluwer Academic Publishers, 19-50.

Waltman, L./Tijsen, R.J.W./Van Eck, N.J. (2011): Globalisation of science in kilometres, Journal of Informetrics, 5, 574-582.

Wang, J. (2012): Citation time window choice for research impact evaluation, Scientometrics, 1-22.

Wuchty, S./Jones, B.F./Uzzi, B. (2007): The Increasing Dominance of Teams in Production of Knowledge, Science, 316, 1036-1039.